# DESIGN, HEALTH & CIRCULAR ECONOMY

Aalto University
School of Arts, Design and Architecture
Department of Design
Collaborative and Industrial Design

Manuel Rosales

Master's Thesis | **2019**

**Aalto University**
www.aalto.fi
Master's thesis for Master of Arts.
Author: Manuel Rosales.
Work Title: Design, Health and Circular Economy.
School of Arts, Design and Architecture.
Department of Design.
Programme: Collaborative and Industrial Design (CoID).
Minor: International Design Business Management (IDBM).
Year: 2019.
Page count:102.
Language: English.

Thesis Supervisor: Tuuli Mattelmäki.
Thesis Advisor: Cindy Kohtala.

Aalto University

## ABSTRACT

Products generate waste in a linear value production model design. New sustainable design methods focus on using bio-materials and re-manufacturing processes to decrease waste and impact on the environment. Circular Economy models are sustainable because they aim to keep the value of a product at the end of their useful life. They reintegrate products in the chain instead of becoming waste and lose their value. However, circular models require an understanding of the big picture of business model ecosystems on what, who and how everyone closes the loop. Furthermore, the Internet of Things in product-service systems (PSS) requires the integration of diverse perspectives in their conception and design.

The objective of this thesis is to find a way to create circular PSS concepts in circular economy models through a collaborative design approach. The approach extracts the expertise of other areas to understand the real needs of all stakeholders to close the gap between design and business perspectives. It aims to understand what value means for each stakeholder, the implications of moving towards circular economy models, the impact on the product architecture, the technological trends opportunities and the experiences that the users and customers desire.

The study case for the thesis focuses on chronic diseases in Finland, especially for ischemic heart diseases which are the leading cause of deaths triggered by a cardiac arrest. The cardiopulmonary resuscitation (CPR), and the automated external defibrillator (AED) are fundamental to save a life.

Methods, tools and principles of PSS and circular models, combined with Human-Centred Design (HCD) approaches, identify a problem space and possible solutions for circularity and usability in the study case. The limits of this research are that the time scope for the project only reached the design concept stage, without the implications of standards for medical equipment for a future product development stage.

The outcomes of the research are insights for CPR and AED as a product-service system in circular economy models. However, the principal value is a new canvas that analyses a product -from the perspectives of design, business and technology- to map all the implications required to transform a product into a PSS in a circular model; integrating experts in a collaborative workshop to validate the model.

The complexity of product-service systems in circular models resides in their natural transdisciplinarity. The number of stakeholders and their expertise surpass the knowledge of design to understand their processes. Alongside the contribution of the new canvas, the main conclusion for this work is that transdisciplinary projects could be led through the collaborative design approach under two conditions. The first condition is when the designer understands the meanings of concepts across disciplines, and secondly when the project has access to all the critical stakeholders in the project's ecosystem. Thus, the need for transdisciplinary tools for design approaches requires further analysis and development.



**Key words:** Healthcare, chronic diseases, cardiovascular diseases, circular economy models, product-service systems, collaborative design.


EJK

**ACKNOWLEDGEMENTS**

I want to express my gratitude to my advisor Cindy Kohtala for all her guidance, patience, corrections and tutoring through the learning process of this master thesis. Furthermore, I would like to thank my supervisor Tuuli Mattelmäki for her trustfulness, empathy and support on the way. Also, I want to thank all the participants during the interviews and workshop, who willingly shared their precious time for this project.

Besides, I want to thank all my friends who have been part of this fantastic journey in Aalto. I am grateful to my CoID friends, especially to Jiyoung (Rachel), André, Kata, Eduardo (Lalo), Shreya and Agi (Agnesa); thank you for being my family in Finland. Also, to the "Hang out" (Pdp) friends Laura, Valtteri, Artur, Josefina, Andrés, Esperanza, Sushant, Abel, Pradeep, Paula and Bijan; thank you for all the fun moments we had together. Furthermore, to my IDBM friends, especially to Appurva, Riley (Riia-Leena), Milla, Fiona, Julia, Linh, Zhou, Leo, Ira and Bernadett; I value your friendship and time during the minor. Last but not least, the Aalto Explorer team, thank you Oskari, Loi, Adriana, Arpita, Maimuna, Izzan, Henri and Riku for your friendship and trust. I am especially grateful to Eva (CIDI) because, in the most challenging moments, she was always there to comfort me.

Finally, I want to thank my family that supported me during my master studies abroad, and I will be grateful forever for all your love. Also, I am thankful to my oldest friend Beatriz -and Moreno family- for receiving me in Norway before moving to Finland. I want to thank Alejandra (Alelo) for being part (remotely) of this journey. I will always cherish forever all the moments we were together.

Manuel.

**TABLE OF CONTENT**

## INTRODUCTION

Health is a state of physical, mental, and social well-being. It is the condition of the body and the degree to which it is free from illness, or a state of being well (Cambridge, 2019). All countries around the world face similar problems and challenge to increase health and prevent diseases in their population. The need for healthcare products and services requires investment from when we are born until the last stages of our life.

The development of health technology required for diseases' treatment increased our life expectancy. However, while fatal infectious diseases decreased in developed countries, chronic diseases and accidents increased, due to our current way of life and conditions that compromise our health and well-being.

Furthermore, health services and products are one of the most complex and challenging areas for design due to international standards restrictions for sterilization and health risks that the process involves. Designing products in circular economy models is a trend that companies started to implement in their business models to be more sustainable, modifying their linear manufacturing processes to keep the value of their products circularly. The application of circular economy models in health design is in the early stages, and only a few articles are written about the topic.

With the megatrend of digitalization, the Collaborative Design approach started to become more pertinent and relevant, broadening new areas of design, such as service design, interaction design, and user experience design. On the other hand, most of the traditional industrial design nowadays requires integrating emerging technologies related to the Internet of Things (IoT), likewise new biomaterials on their design. As design approaches diverge, the role of the designer does too. However, a point in which all of them converge is the Product-Service Systems (PSS) because they combine services, products, and business models as a single product.

Human-Centred Design (HCD) focuses on the users' usability and useful systems, applying human factors and usability knowledge; most of the health companies understand its value, and they integrate it into their processes gradually. PSS requires the expertise of other fields, they involve more stakeholders, and designers' knowledge in HCD has boundaries related to the designer's experience. The collaborative approach crosses the limits of Human-Centred Design to extract the knowledge that designers require from areas outside the design field.

This thesis aims to explore new possibilities of circular design concepts through a collaborative design approach, using chronic diseases in Finland as a case of study, specifically in cardiovascular diseases. As the topic is narrowed and framed, the ischemic heart disease appeared as the first cause of death in Finland, caused by the most lethal complication of this disease: a cardiac arrest.

To address that complication, the 'automated external defibrillator' (AED) device and 'cardiopulmonary resuscitation' (CPR) procedure are crucial. Thus, they are a promising problem and opportunity space. The AED device is analyzed as a study case to make it a PSS in a circular model, using a collaborative approach as a way to validate the PSS proposal among the stakeholders, as well as identifying new collaborations between the stakeholders in a circular business model.

The learnings from Collaborative and Industrial Design (CoID) and International Design Business Management (IDBM) minor provide the required knowledge for this analysis, to close the gap between Design and Business perspectives.

# 01
# BACKGROUND

### 1.1 Healthcare in Finland

The first step in this research is understanding the healthcare context in Finland first from a general international perspective, then as a member of the European Union (EU), and finally narrow it to a particular perspective of the country, which in this case are chronic diseases.

Healthcare is one of the world's largest sectors. In terms of well-being, according to the Better Life Index from the Organization for Economic Cooperation and Development (OECD) in 2018, Finland is on the 15th place of 38 countries in the life expectancy index indicator. In Finland, life expectancy at birth is 82 years, two years higher than the OECD average of 80 years, and 70% of people reported being in good health, slightly higher than the OECD average of 69% (OECD, 2018). This index indicator is relevant because a higher life expectancy is associated with higher health care expenditure per person, although many other factors have an impact on life expectancy, such as public health interventions, living standards, lifestyles, education, environmental factors and progress in medical care (OECD, 2018). With the rapid decline in mortality from infectious diseases, chronic diseases and injuries have become Finland's major causes of premature death. The mortality rate of these factors has declined over the past few decades, which has resulted in a significantly longer life expectancy (National Institute for Health and Welfare, 2019).

Chronic diseases and disorders also result in high mortality rates; they are critical issues of public health. One of four Europeans suffers a health problem that restricts their daily activities. Besides, chronic diseases affect 2/3 of populations above 65 years old; they undergo one or more chronic diseases, which means that they reduce their quality of life and experience financial and social struggles. The most frequent chronic diseases are diabetes, heart disease, strokes, and mental conditions. The main reasons that trigger chronic diseases are sugar, smoking, inactivity, and alcohol; reducing those risk factors prevents 80% of the most common chronic diseases (CHRODIS, 2018).

In Finland, cardiovascular diseases, diabetes, asthma and allergies, chronic respiratory diseases, cancer, memory disorders, musculoskeletal diseases, and mental disorders are chronic diseases and conditions that are considered critical of public health (National Institute for Health and Welfare, 2019).

### 1.2 Health Technology in Finland

How big is the market for health technology in Finland? The EU health sector, for instance, accounts for 10% of gross domestic product (GDP), 15% of public expenditure and 8% of the EU's workforce from an economic perspective (Voudrias, E. 2018: 2). In

the EU, 70% to 80% of the healthcare budget is spent on treating chronical diseases, more than 700 billion euros every year. Besides, 97% of that budget is devoted to treatment, chronic disease management, and healthcare administration, while the remaining 3% is devoted to prevention (CHRODIS, 2018).

In terms of health technology, Health Design Capital (2018) reports that Finnish health tech exports are worth 2.2 billion euros in the market in 2017 (P.5) (Figure 1). In the same year, exports grew by 5.3% for health technology products. Over 80% of those products are exported to other countries, such as the United States – 38% of all health technology export- and China. In fact, Helsinki is home to nearly 500 medical tech and life science businesses. Approximately 100 of them provide facilities for production, design, clinical research and regulation that are used by large companies and start-ups alike (Health Capital Helsinki, 2018: 4). Health technology companies in Finland represent a broad industry sector, from monitoring and imaging equipment and diagnostics to services (Figure 2). New technologies that involve IoT, such as artificial intelligence, robotics, and virtual reality, allow potential innovation opportunities for new health technology of products and services.

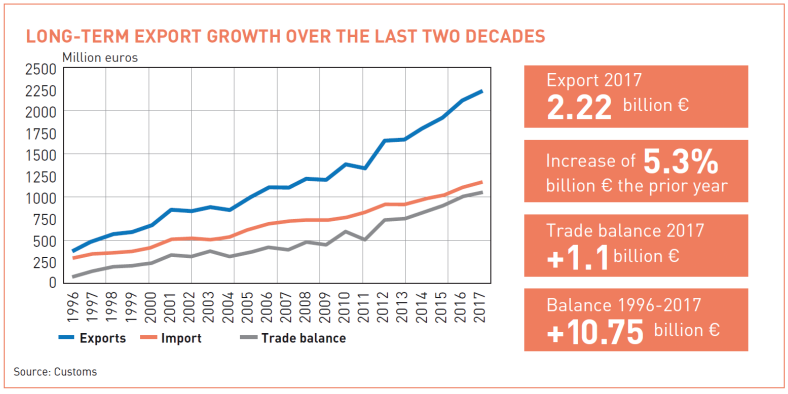



Figure 1. Finland's health technology exports growth (Healthtech Finland, 2018: 5)

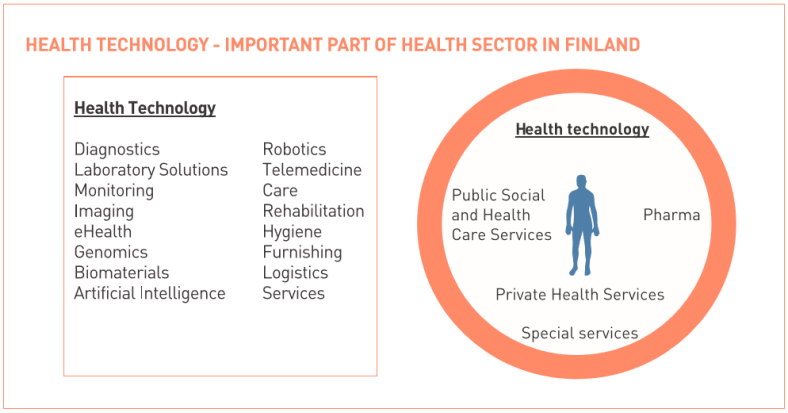



Figure 2. Health Technology areas in Finland (Healthtech Finland, 2018: 3)

### 1.3 Circular Economy

Industrial designers have a direct relation with emissions on the products that are designed every year around the world. An estimated 80 per cent of a product's environmental impact is determined at the design and development stage (Charter, M., 2019: 24). Due to this fact, the circular economy is a growing trend that aims to reduce emissions, increasing the lifespan of products through recycling, renewing, remaking and share models. The aim is to maximize the time of products, components and materials that are kept in use; it is an endless cycle that captures untapped value potentials of the traditional "take-make-dispose" value chain (SITRA et al., 2017: 5). Moving towards a circular economy model is decisive for innovation and growth. Circular models can be applied across the whole value chain; however, the best value potential resides during the product usage phase (SITRA et al., 2017: 5).

In circular economy models, three drivers shift a model from linear to circular: customer-centricity, sustainability, and enabling technologies (Figure 3) (SITRA et al., 2017: 12). The customer-centricity, the first driver that has a similar approach as human-centred design, delivers the real users' needs understanding why, how, and what the customer (user) value and is meaningful for them. The second driver, technology, which are, for instance, emerging technologies derivate from IoT, sensors, and artificial intelligence (AI), can increase the value by enabling high lifetime revenues through new solutions that those technologies enable. The third driver, sustainability, means managing a responsible use of natural resources to reduce emissions that improve resource utilization.

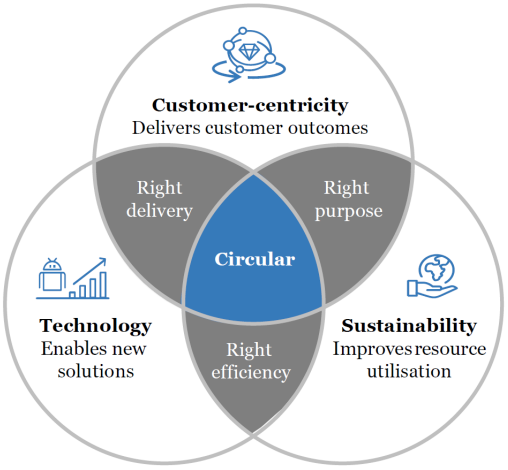



Figure 3. Drivers for circular economy (SITRA et.al. 2017: 12).

The result of those drivers applied to the traditional linear value chain are five circular business models and their sub-models that companies should explore: Circular supply chain, Sharing Platform, Product Life Extension, Recovery & Recycling, and Product as a Service (Figure 4 and 5) (SITRA et al., 2017: 20).

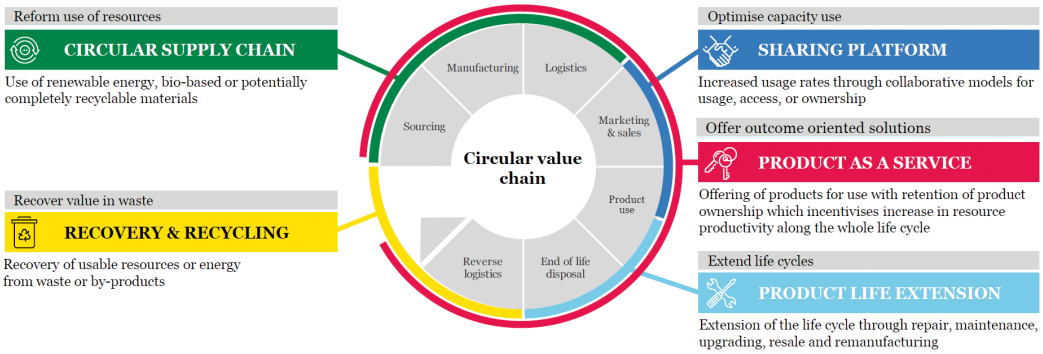



Figure 4. Circular Economy Models (SITRA et.al. 2017: 24).

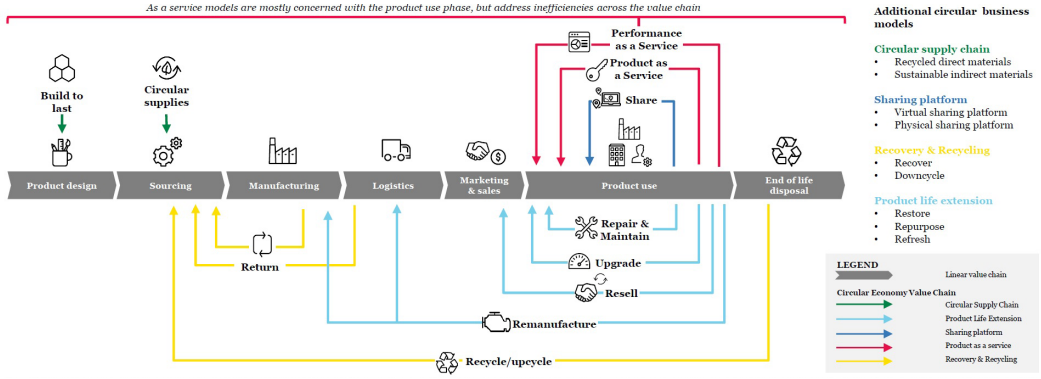



Figure 5. Illustrative Circular value chain, models and sub-models (SITRA et.al. 2017: 25).

It is necessary to understand the characteristics and differences in each circular model and their sub-models to find design opportunities. As mentioned before, the objective of circularity is to keep the value of the products in the value chain, trying to close the loop on all the stages.

### Circular Supply Chain Model

This model in the value chain focuses on the "product design" and "sourcing" stages. It can be divided into two sub-models "Build to last" and "Circular supplies" (SITRA et al., 2017: 26). The first submodel aims to design products (from their conception) that are durable and easy to repair; for instance, modular product architectures of pieces and components (Ulrich, K., 1995: 6). The second one focuses on the use of renewable energy, bio-based materials, or potentially wholly recycle materials. In design, this model is related to the "cradle to cradle" sustainable design approach to develop high-quality products that are eco-effective instead of eco-efficient (van Boeijen, A. G. C. et al., 2013: 35).

### Recovery & Recycling Model

This model aims to recover useful resources or energy from waste or by-products from the "manufacturing", "logistics" and "end of life disposal" stages to the "sourcing" stage in the value chain (SITRA et al., 2017: 24). It can be divided into two sub-models "recycle/upcycle" and "Return". The first sub-model collects and recovers materials of end-of-life products and reuses them in their production (e.g., Pure Waste, an apparel company in Finland that uses waste textiles as their raw material). The second sub-model returns wasted parts and materials from the manufacturing process to the sourcing stage.

### Sharing Platform Model

This model aims to increase usage rates through collaborative models for usage, access, or ownership during the "product use" stage on the value chain (SITRA et al., 2017: 24). This submodel divides into physical or virtual sharing platforms (e.g., UBER freight).

### Product Life Extension Model

The model aims to extend the life cycle of a product through repair, maintenance, upgrading, resale, and remanufacturing (SITRA et al., 2017: 24). These sub-models begin in the "Product use" stage; the products are reintegrated into "manufacturing", "logistics", "marketing & sales" and "product use" stages on the value chain. Products in the use stage with modular architectures allow changing specific parts or components of them in this model, even if they were not designed to be circular.

### Product as a Service Model

This model offers products to customers as a lease, in which companies keep the ownership. Thus, the model increases resource productivity throughout the whole life cycle. The sub-models can be divided into "product as a service" (e.g., Voi scooters) or "performance as a service" (e.g., Philips Circular Lighting service) (SITRA et al., 2017: 24).

### 1.4 Implications for the Circular Economy in Health Design

After understanding the models and sub-models of the circular economy, the next step is to understand the implications of how health design integrates into those models. In the medical sector, although it produces a significant amount of waste, it is challenging to apply circular design principles because of the patient health and sterility challenges involved in the reuse of products or materials (Kane, Bakker & Balkenade, 2018: 1). The amount of waste produced per hospital patient per day ranges from 0.44 kg in Mauritius to 8.4 kg in the United States, with EU countries appearing to be between these two extremes (UK 3.3 kg, Germany 3.6 kg and France 3.3 kg) (Minoglou et al., 2017). Furthermore, in the US, an additional 50,000 tonnes per year is estimated to be generated from home healthcare (Kaiser et al., 2001). This situation is why it is such a compelling design problem.

In design, it implies analyzing which parts of health products are the ones that can be modified on their architecture to be more circular, particularly the ones that are a hazard for health in terms of infectious waste management. The reason why medical devices become waste, in a linear value chain, is obsolescence. Defined by den Hollander et al. (2017), obsolescence is a loss of perceived value of the product, which leads to being discarded from the economic system. Hollander et al. classify obsolescence in five types:

- Functional obsolescence: the product no longer performs its intended function.
- Technological obsolescence: the product is outperformed by newer technology.
- Economic obsolescence: the product's use is no longer profitable.
- Regulatory obsolescence: the product is no longer legal.
- Aesthetic obsolescence: the product is outmoded, or its aesthetic appeal is damaged.

In order to keep the value of medical products that become obsolete and identify which products in the medical sector are feasible for circular economy models Kane, Bakker & Balkenade (2018) proposed design strategies for recovery of circular medical products concerning product criticality and product value metrics (p. 43). Using these strategies (Figure 6), we can identify and classify which products can be recovered through different processes, such as reprocessing, refurbishment, or recycling (Kane et al., 2018: 43).

While design strategies to recover medical products from Kane et al. focus on a "product life extension" circular model, another path is through a "Product as a Service" model that SITRA (2017) proposed. To offer a product as a service, it implies to have knowledge and understanding of both product design (understood as hardware) and service design. For this purpose, a Product-Service System (PPS) approach,

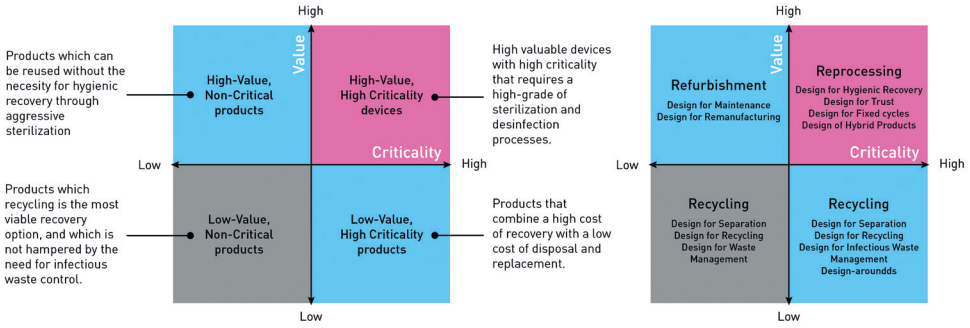



Figure 6. Design strategies for recovery of circular medical products in relation to product criticality and product value. (Kane, Bakker & Balkenade. 2018: 45)

which has a direct relation with the three drivers of circularity -customer-centricity, sustainability and enabling technologies- proposed by SITRA et al. (2017) could be an approach to explore product as a services model. According to Vezzoli, C. Kohtala, C. Srinivasa, A. et al. (2014:31), the definition of an eco-efficient PSS proposed by Learning Network on sustainability (LeNS) project explain clearly this approach:

> ***"...an offer model providing an integrated mix of products and services that are together able to fulfil a particular customer demand (to deliver a 'unit of satisfaction') based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the providers continuously seeks environmentally beneficial new solutions" (Vezzoli, C. Kohtala, C. Srinivasa, A. et al. 2014).***

Based on this definition, PSS satisfy customers' demands, and opportunities emerge for all the stakeholders involved in those systems through new business model innovations. The PSS approach could be an excellent way to explore innovation in "Product as a Service" models and sub-models (SITRA, 2017). Besides, in relation to chronic diseases and services, Manonen et. al. (2107: 5) found that the meaningful experiences -for patients and their families with those illnesses- is when they find the correct medicine and treatments and learn how to live with them (self-management), acquiring new knowledge or a new perspective about the illness.

From a design perspective, the transition towards Circular Economy (CE) models needs to be more focused on changing the mindset of consumers and users of products, in terms of being more aware of the materials and components within

them (Charter, M., 2019: 28). Thus, the value proposition of circular models should reflect more extensive environmental and social benefits (Martin, C., McLanaghan, S., 2019: 91). From a business perspective, it will be keeping the product's value by innovating adding new activities, linking activities in a novel way, or changing which party performs an activity in the business model (Amit, R., Zott, C. 2012: 39). It will be crucial for the design stage to understand where the innovation strategy will be focused: on the business model, the product architecture design, or both for products and services in the circular models.

The relations between the spheres of circular models, healthcare, and design, are challenging and complex (Figure 7). Besides the vast information content of each sphere, what is complex about these relations is that they involve different stakeholders -companies, customers and users- and their perspectives about the value of products/services and how meaningful they are for each of them. As these type of research requires the expertise of different stakeholders, the hypothesis of this thesis is to use the collaborative design approach as a way to involve them as design partners to help to determine real needs related to products and services (INUSE Research Group, 2017) for patients with chronic illnesses.

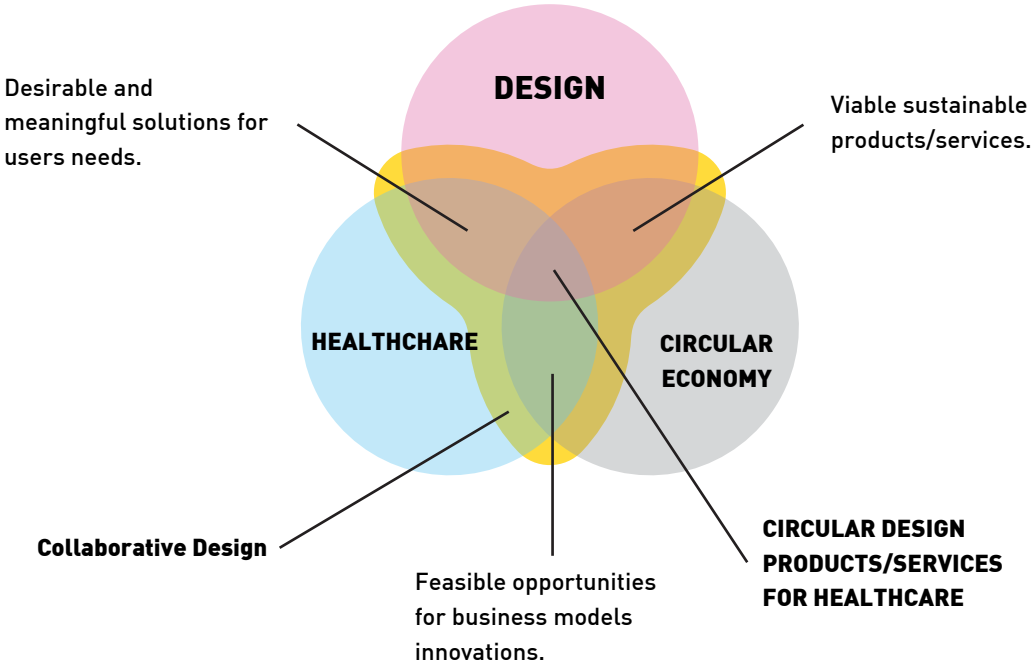



Figure 7. Spheres relational hypothesis (Diagram by the author).

# 02
# RESEARCH OBJECTIVES, AIMS & QUESTION

## RESEARCH OBJECTIVES, AIMS AND QUESTION

The purpose of research is to learn what has never been known before, to ask an important question which no conclusive answer has previously been found; and, by collecting and interpreting relevant data, to find an answer to that question (Leedy and Ormrod, 2010: xvi).

Considering that the EU dedicates 3% of the healthcare budget to prevention (CHRODIS, 2018) and that chronic diseases are critical public health issues in Finland (National Institute for Health and Welfare, 2019); there is a need for design solutions for prevention, monitoring, and treatment of chronic diseases. Besides, the megatrend of the ageing population will increase the problem, because 2/3 of adults in the EU above 65 years old suffer at least one or more chronic diseases (CHRODIS, 2018).

These new solutions require to be sustainable because countries in the EU like UK or France generate 3.3kg of waste created per hospital patient per day, while countries like the US generate more than 8.0 Kg (Kaiser et al., 2001). Thus, circular economy models become relevant in health design projects because the challenge is how to include new services and products into them.

The collaborative design is defined by the INUSE research group (2017) as an approach -belonging to a cooperation cluster together with co-design- in which users are taken as design partners or experts of their work, to determine the needs and requirements for products or services. The designer's role in this approach is to facilitate and organize that collaboration with tools that help users to design.

The objectives and aims of this thesis research study are:

1. To identify a potential design product that can be transformed into a product-service system for healthcare; that integrates circular economy models, using chronic diseases in Finland as a context to improve well-being, decrease waste, and reduce resource consumption.

2. To generate design concepts and identify circular design opportunities, through Human-Centred Design approach, that improves the service/product based on the case study stakeholders.

3. To design a tool or process in collaboration with experts of other fields that help to integrate product-service systems and circular models, considering the design, business and technology perspectives.

Considering the objectives, the study case and the relational spheres of this project, the main research question is:

**IN THE CONTEXT OF HEALTH CARE:**

# HOW MIGHT WE DESIGN PRODUCT-SERVICE SYSTEMS IN CIRCULAR ECONOMY MODELS THROUGH A COLLABORATIVE DESIGN APPROACH?

# 03
# METHODS

## METHODS

As the collaborative design will be the primary approach for this project, the selection of the appropriate methods is crucial to lead the design process. This study uses qualitative research methods and design methods to ensure the relevance of the outcomes.

Qualitative research is in-depth subjective research. It is the type of research that we can use when there is a little information on the topic of interest when the variables are unknown, or when the relevant theory base is inadequate or missing (Muratovski, 2016: 48). For instance, in-depth interviews will provide qualitative data about the experience and perspective of stakeholders. In contrast, quantitative research generates statistics, describing a particular phenomenon, or identifying cause-and-effect relationships. In this thesis, quantitative research was not conducted, but quantitative studies by other researchers were relevant in the case study research.

### 3.1 Case Study

> ***"Case study research is an approach that can provide the tools to study a complex or a little-known phenomenon by using a variety of data. This approach can allow to conduct an in-depth investigation into a person, programme, or event for a defined period of time and within a context" (Muratovski, 2016: 103).***

All the data collection from a study case comes from diverse documented sources, such as direct observations, participant observations, interviews, documents, newspaper articles, official records, physical artefacts, and various audio-visual materials. First, data is organized, analyzed and categorized, then patterns are identified, and the information is synthesized and generalized. (Muratovski, 2016: 103).

The case study approach can help to acquire information related to the stakeholders and the context if there is an open database with records about chronic diseases. This method relies on previous works and publications, which means that this is not a method to generate new information. For an international student in a not known context, the case of study is a suitable approach for this research as long as the sources are reliable. To contextualize the study case for this research, literature documents from renewed national and international institutes, academic research articles, and non-governmental organizations' publications were consulted.

### 3.2 Human-Centred Design

> ***"Human-centred design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety and performance" (ISO, 2010)***

This approach is useful when designers want to analyze a specific interaction between the user and a particular product. In the case of this research, the approach can provide data on existing medical devices related to the current interaction and its effectiveness and efficiency between users-products. In case a specific product requires an analysis of its interaction and performance, this method reveals the problems that need to be solved based on the users' needs. Methods as in-depth interviews and field observation will disclose valuable information about issues that need to be solved concerning a product.

### 3.3 Product-Service System

PSS expands product development beyond the product itself. The activities and knowledge associated with PSS lead to the need for more holistic design processes, which includes the design of both products and services that takes a much broader life cycle perspective (Mc Aloone & Pigosso, 2019: 103). PSS design and development involves the consideration of four fundamental dimensions: value proposition, offering life cycle, user activity cycle and ecosystem (Figure 8). Besides, each of its dimensions goes through analysis, definition, conceptualization, and evaluation stages (Mc Aloone & Pigosso, 2019: 103).

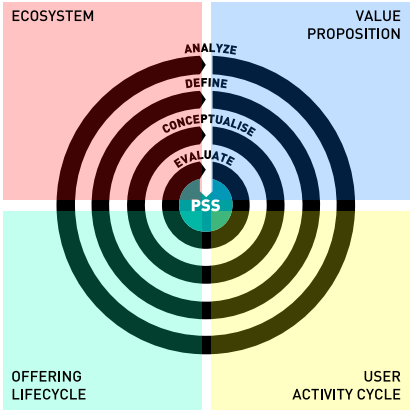



Figure 8: PSS methodological reference model (Finken et. al. 2013)

This method process allows perceiving the big picture for a product-service system concerning the circular economy and business models. The process validates the design concepts in circular models. However, this method requires to understand the meanings of value and ecosystem in the business perspective, to conceive its four dimensions.

# 04
# CASE STUDY

### 4.1 Ischemic Heart Disease

In Finland, the chronic diseases considered critical public health issues are the cardiovascular diseases, diabetes, asthma and allergies, chronic respiratory diseases, cancer, memory disorders, musculoskeletal diseases, and mental disorders (National Institute for Health and Welfare, 2019).

The Institute for Health Metrics and Evaluation (2019) reported in their ranking of top 10 causes of death in 2017 in Finland that ischemic heart disease is on the first position, followed by Alzheimer's disease on second place and strokes on third place respectively. Besides, in a report entitled 'Noncommunicable diseases (NCD) Country Profiles' from World Health Organization (2018) in Finland 36% of 53,000 deaths in 2016 associates to cardiovascular diseases (Figure 9). Among them, the most common ones are ischaemic heart disease, congestive heart failure and disorders of the cerebral circulation (National Institute for Health and Welfare, 2019).

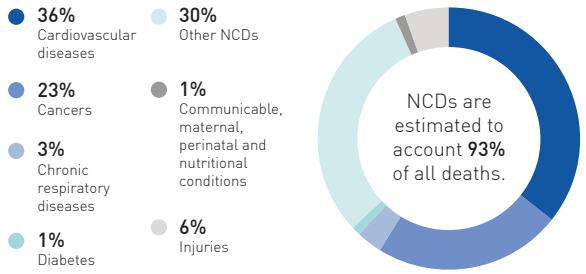



Figure 9: Finland Proportional Mortality (WHO, 2018).

Data from different sources reveals that the main problem in Finland -related to chronic diseases- is the cardiovascular diseases, specifically the ischaemic heart disease, considering the percentage of deaths and its first place in the ranking of causes of death. The treatment for this disease focuses on hearth-healthy lifestyle changes, medication and procedures. However, the most severe risk of this disease is the complications it can trigger. The 'National Heart, Lung and Blood Institute' (2019) enlisted the serious ischaemic heart disease complications:

- Acute coronary syndrome, including angina or heart attack.
- Arrhythmia.
- Cardiogenic shock.
- Heart Failure.
- Stroke.
- Sudden cardiac arrest.

From all the complications, cardiac arrest is the most fatal because it leads to death within minutes. This complication is unpredictable; it may occur at any place and time, which means that a person in such a situation requires immediate attention to avoid death.

### 4.2 Cardiac Arrest

***"Every year about 5,000 Finns get cardiac arrest outside the hospital. Only about 250 of them survive. Seven out of ten can be saved with a defibrillator" (Servicia Medical, 2018).***

***"Each year in the United States, more than 350,000 cardiac arrests occur outside of a hospital setting" (American Heart Association, 2019).***

Cardiac arrest is the abrupt loss of a heart function in a person. The cause is related to the heart's electrical system malfunctions, often caused by irregular heart rhythms, called arrhythmias. The heart stops beating properly. Thus, the heart's pumping function is 'arrested' or stopped (American Heart Association, 2019).

This complication is often mistakenly with 'heart attack'; the main difference is that the cause of heart attacks is a blockage that stops blood flow to the heart; it is a circulation problem. While a cardiac arrest is an electrical system malfunction, it can occur after a heart attack, or during the recovery of a patient (American Heart Association, 2019).

In a cardiac arrest, biological death can result if the heart is not reactivated within 10 minutes after it started. The heart can be reactivated through a 'cardiopulmonary resuscitation' (CPR) procedure, combined with the use of a defibrillator (American Heart Association, 2019).

The 'American Heart Association' (2019) proposed an Out-of-hospital Chain of Survival (Figure 10), which are a series of steps that provide a useful metaphor for the elements of the emergency cardiovascular care (ECC) systems concept. The five links in the chain are:

1. Recognition of cardiac arrest and activation of the emergency response system.
2. Early cardiopulmonary resuscitation (CPR) with an emphasis on chest compressions.
3. Rapid defibrillation.
4. Basic and advanced emergency medical services.
5. Advanced life support and post-cardiac arrest care.

Effective implementation of the chain of survival can improve the chances of survival and recovery for victims of cardiac arrest. In the chain, the defibrillator has a high criticality in an emergency; it reactivates the heart rhythm. Besides, it has a medium-high value for public spaces managers. The AED (as the product) and CPR (as the service) high appreciation, indicate that they are a good case of analysis for the project.

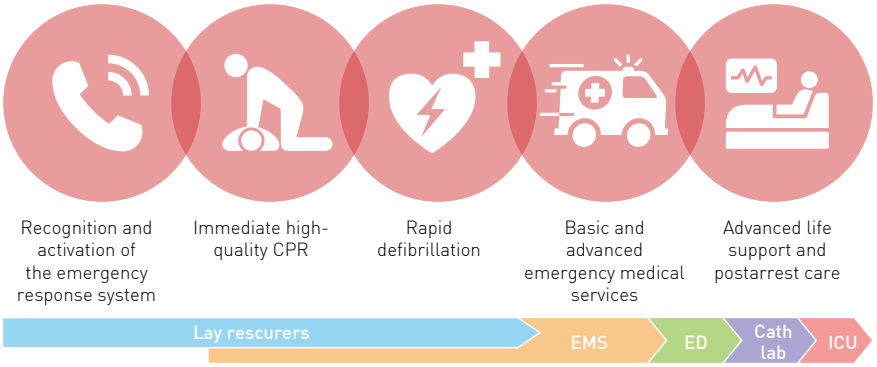



Figure 10. Out-of-hospital Chain of Survival (American Heart Association, 2019)

### 4.3 Automated External Defibrillator (AED)

Defibrillators are devices that restore natural rhythm by giving the heart an electrical pulse or shock. These are used to correct an arrhythmia, an irregular or too sluggish or too fast pulse. If the heart suddenly stops, defibrillators will restart the beating of the heart (NHLBI, 2019). There are three types of defibrillators: Automated External Defibrillator (AED), Implantable Cardioverter Defibrillator (ICD), and Wearable Cardioverter Defibrillator (WCD).

An AED (Figure 11) is a lightweight, battery-operated, portable device that checks the heart's rhythm, and if necessary, discharge a shock to the heart and restore its normal rhythm to treat a cardiac arrest (NHLBI, 2019). The device delivers a shock through sticky pads with sensors, called electrodes, that are attached to the patients' chest that is having a cardiac arrest. The electrodes send information about the person's heart rhythm to the AED computer, and it analyses it to find out whether an electric shock is needed. (NHLBI, 2019).

This device is used to help a person having a sudden cardiac arrest. They are located mainly in public spaces near the entrance of a building. These devices combined CPR (Figure 12) increase the chance of survival of a person. Besides, its design should be for easy use by untrained bystanders through audio and visual commands.

Universal AED Sign [International Liaison Committee on Resuscitation, 2008).


Image: AED location in Väre, Otaniemi campus.

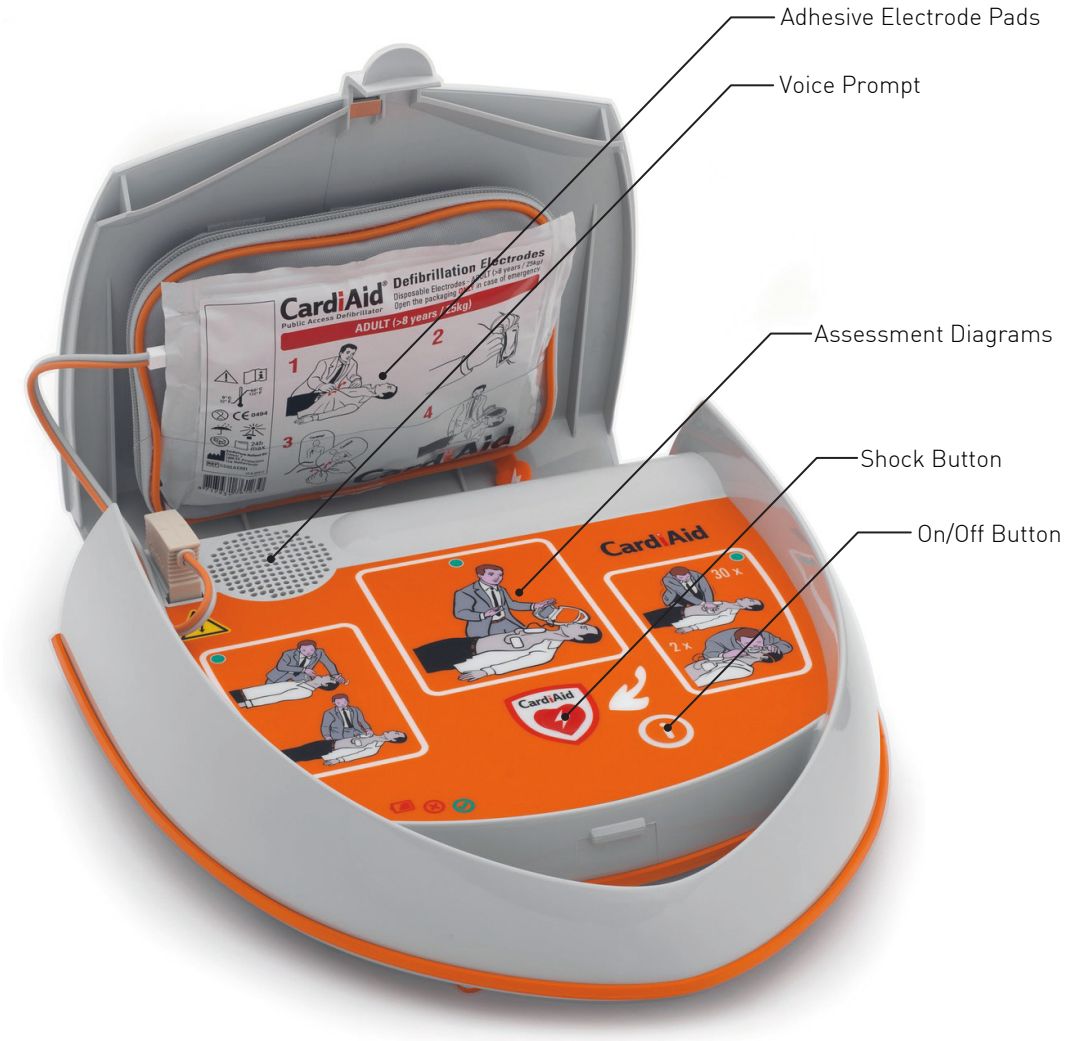



Figure 11: Image of an AED [Needpix, 2019].

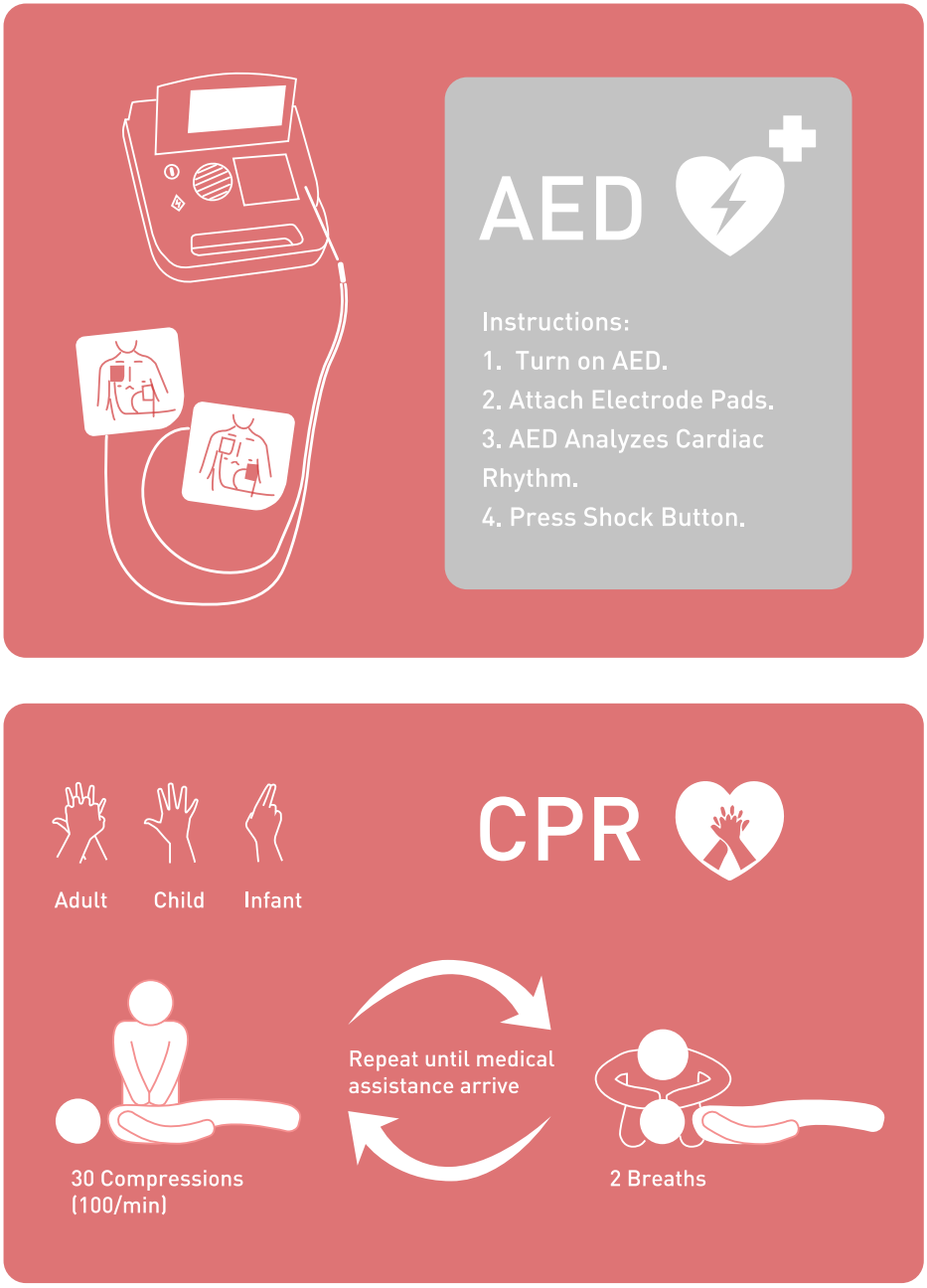



Figure 12: AED and CPR procedures.

### 4.4 Case Analysis & Opportunities

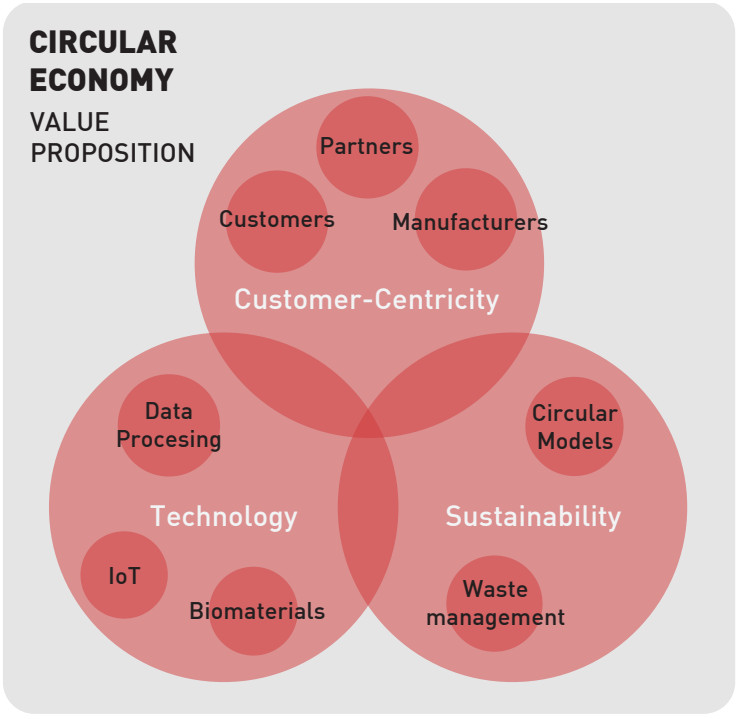
Mapping the AED on the 'Design strategies for recovery of circular medical products' from Kane et al. (2018), the device has a high criticality because it is a device that restores a normal heart rhythm from a cardiac arrest. The device also has a high value because the investment for each of these devices is between 150e to 1200e each. A high criticality and value make the AED a possible candidate for different circular models because it is a device that does not require a high grade of sterilization. Furthermore, analyzing the AED devices through the three drivers for a circular economy (sustainability, technology and customer-centricity) that SITRA (2018) proposed revealed interesting findings for new design opportunities.

Beginning with the sustainability driver, one way to improve the resources of this device is related to the electrode pads and batteries. Both components have functional and regulatory obsolescence (Hollander et al., 2017); they are disposed of, either because of low battery power or the electrode pads' adhesive had deteriorated and expired. Such a situation happened in July 2017 at Hanley in the United Kingdom, when half of the defibrillators in the area were at risk of failing, compromising their reliability and generating waste (Henley Standard, 2017).

Related to the second driver, technology, this device has a great potential to be integrated into the Internet of Things (IoT) and implement new materials or bio-materials in their components to make them more sustainable. Having this device connected to the network will allow monitoring the device status in real-time, and with the megatrend of digitalization, it may be able to link with some other services that could increase its value.

Finally, the third driver, customer-centricity, required a more profound analysis. AED are products located often in public spaces, which means that the customers are public or private institutions, government, schools, shopping malls and other stakeholders that have persons in public spaces. From a business model perspective, new partners and relationships with manufacturers can be created. From the design perspective, the users (not necessarily the customers) that receive the benefit from the AED are passive; in this case, a person who is suffering a cardiac arrest. The active user, the one who uses the product directly, do not receive a direct benefit but is the one that can rescue the person in a cardiac arrest. It means that the value of the product differs between customers and users; even the experiences interacting with the device are not the same.

In conclusion, AED devices have an excellent opportunity to reintegrate them in the value chain through different circular models. In this particular case, the models that have a high potential for exploration are circular supply chain, product-life extension and product as a service. The complexity between customers and users concerning the value and meaningfulness of the device for each stakeholder requires a collaborative design approach to identify all their requirements and expectations for AED devices (Figure 13).




PROBLEMS
Batteries and PADs reliability.

PROPOSED CIRCULAR MODELS
Product as a Service.
Product Life Extension.
Circular Supply Chain.

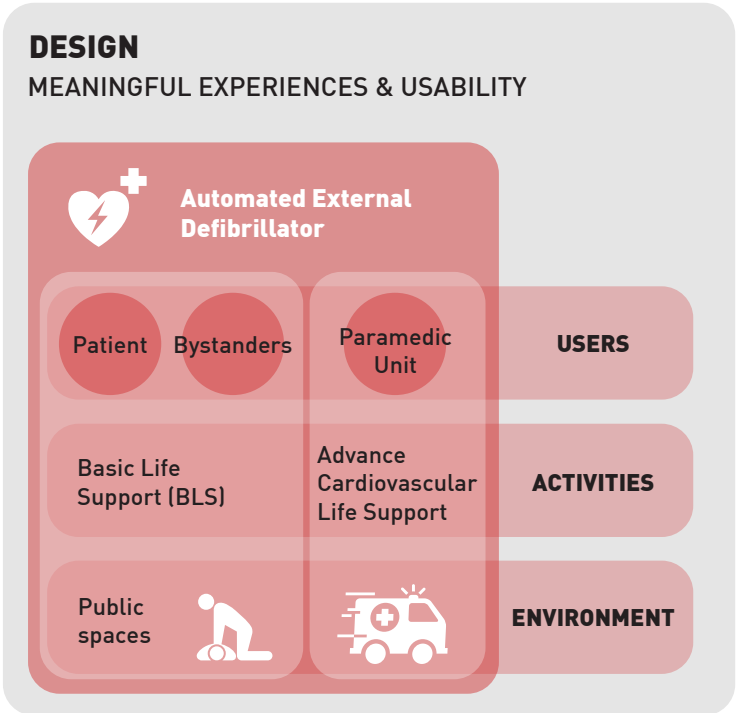



Figure 13: Circular Economy and Design implications for AED. (Diagram by the author)

# 05
# FIELD RESEARCH & INSIGHTS

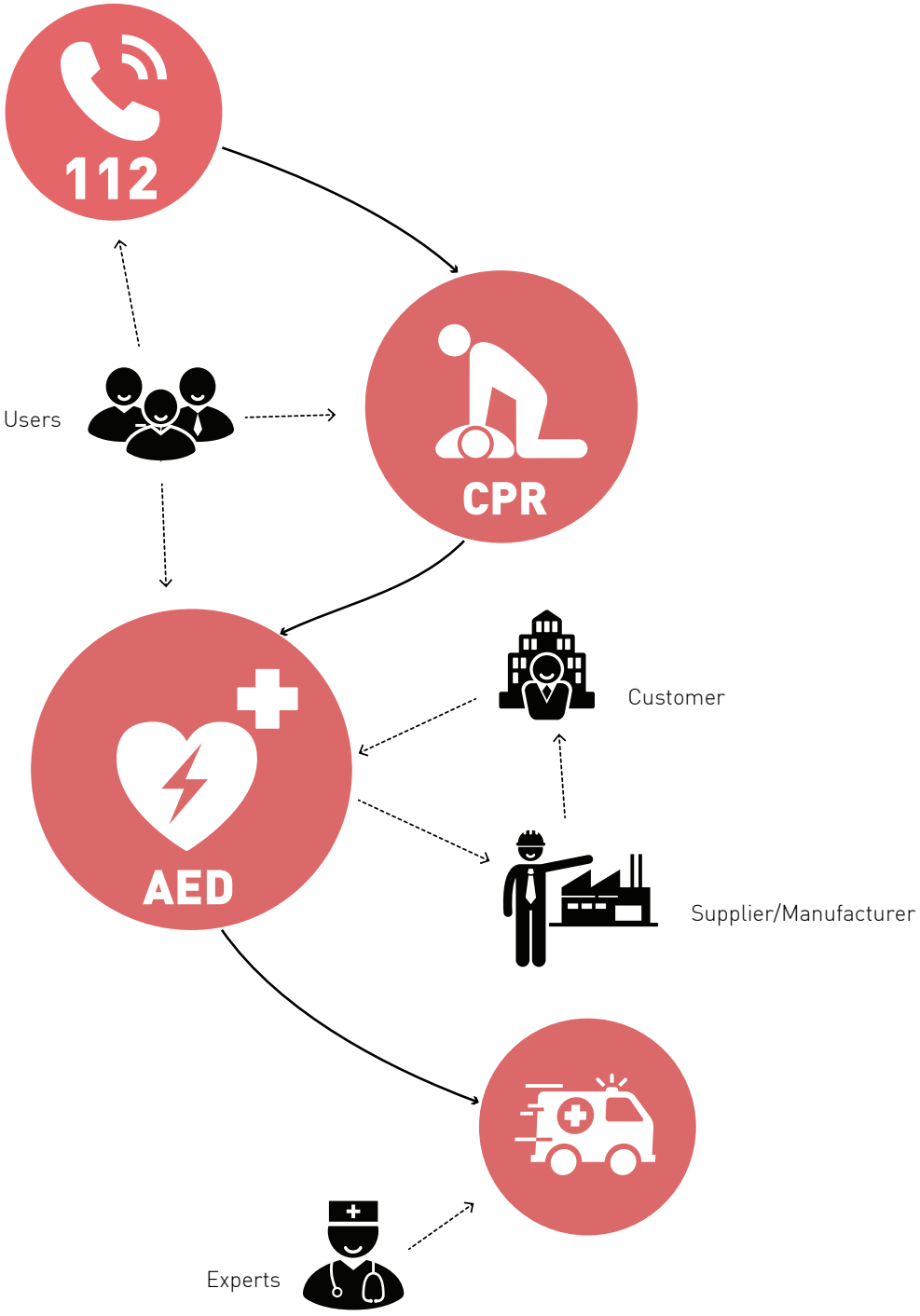



Figure 14: Stakeholders' role during a cardiac arrest (Diagram by the author).

### 5.1 Stakeholders' Selection

Narrowing the topic from chronic diseases to a cardiac arrest helped to identify the product and the stakeholders involved (Figure 14). In-depth interviews with them reveal their experiences, pains, gains, value about CPR and AED devices, and waste management awareness; this type of interviews generate valuable qualitative information that only the stakeholders possess. Furthermore, It is also a way to understand the problem, value and meaning of those from different perspectives towards the same topic. Considering CPR and AED devices as an integrated product-service system, the interviews aim to identify insights that can be used to design circular models and improvements for the service and product.

The stakeholders that are directly involved in a cardiac arrest are the patient, bystanders, paramedics, facility managers and manufacturers. Moreover, to understand the general perspective in the medic field about chronic diseases, general physicians were included for the interviews. However, patients that experienced a cardiac arrest were discarded. There were two main reasons for this decision; first, due to the difficulty of access to patients with cardiac arrest; second, because the processing time that the ethical review committee of Aalto University will take to approve the interviews with patients will be longer for the project time scope.

Ethical procedures for academic research undertaken in Aalto University's Design Department do not require written forms when interviews are not in collaboration with companies or when they do not require to be approved by the ethical committee. However, consent forms were created to keep confidential data safe for the interviewees, as well as a quotation agreement to use the material in this document. The consent form template, as well as the interviews protocols, can be found at the end of this document in the appendix.

## 5.2 Interviews' protocols

Different interview protocols created guided the stakeholders' interviews. The general structure of the interviews consisted of four parts: Introductory questions, transition questions, key questions and closing questions. The final participants for interviewees were two physicians, one paramedic, one facility manager, one for bystanders, and unfortunately, none of the manufacturers replied to the interviews' request. The interviews lasted 60-80 minutes, and they were conducted during spring and summer 2019 at Aalto University or the stakeholders' office.

### Physicians

The interview structure aimed to understand from a physician perspective the experiences, pains and challenges of chronic diseases in Finland. Besides, the interview also asked questions regarding waste management and devices' maintenance. The interview protocol was iterated after each interview, modifying some questions based on the answers of the former interviewee. The criteria selection for this group were general physicians from Terveystalo in Otaniemi.

### Paramedic Units

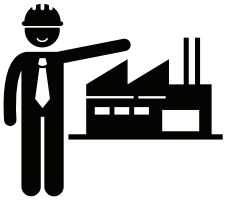
The aim of the interviews for paramedic units was to understand their process when they receive the emergency call to attend a cardiac arrest until they reach the patient. Their experience about the correct use of AED devices and CPR is crucial to highlight the critical moments for patients during the emergency period. Furthermore, it is crucial to understand what is valuable and meaningful for them before, during and after these experiences. The criteria for interviewees' selection were pre-hospital emergency medical technicians, physicians or nurses, who are or were actively working in ambulances.

### Bystanders

The users that interact directly with AED devices are the bystanders; these users could be the building staff or any other person in a public space. The objective of interviews with bystanders was to know from their perspective the experiences they had before or that they would expect if they need to help a person in a cardiac arrest. These

interviews focus more on the interaction with AED devices as well as CPR training experiences.

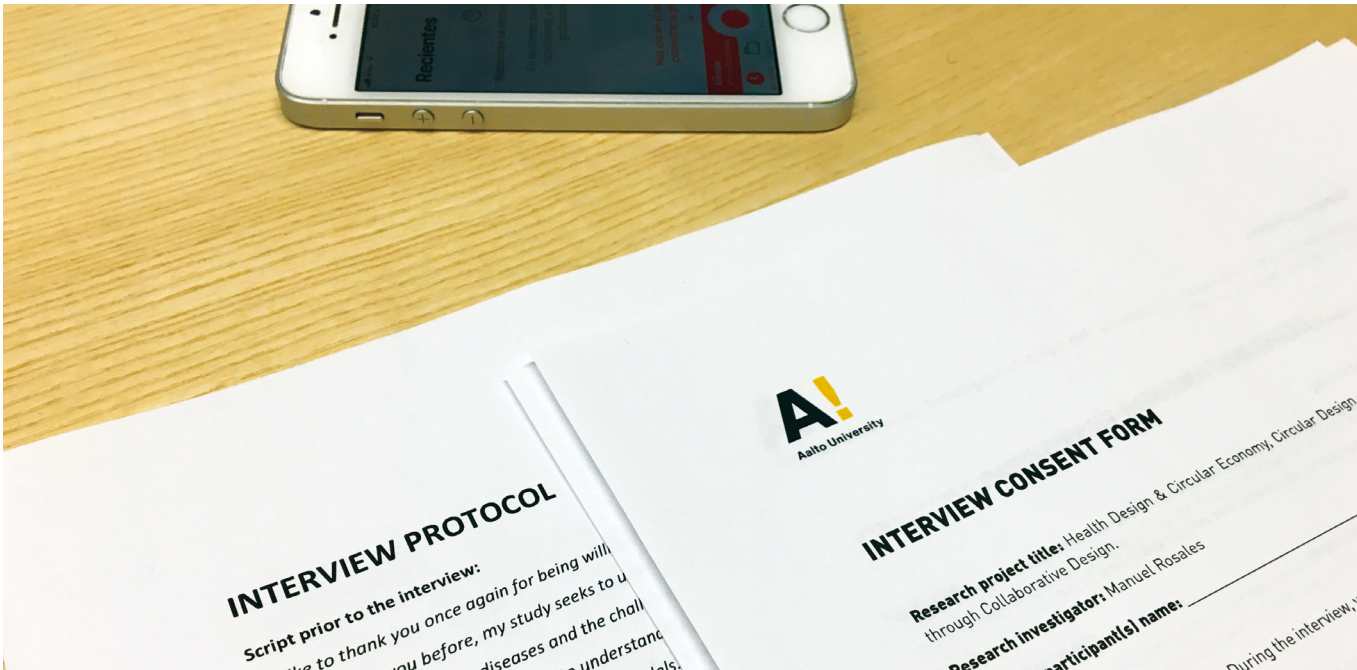
**AED Manufacturers/Suppliers interviews**



The manufacturer's interviews focused more on the product architecture, services, legislation, challenges and opportunities of migrating AED to circular models. Furthermore, these interviews aimed to identify who may be potential partners and understand their perspective about what customers value regarding AED devices. However, information had to be collected from websites.

**Facility Manager**

Facility managers are persons in charge of buildings' management, maintenance and services. These interviews provided information about the value of AED devices (customers perspective), as well as their maintenance process and reliability. For strategic reasons, the interviewee's selection is among the Aalto buildings facility managers, specifically in Väre.



### 5.3 Interviews' Results

PHYSICIANS

Subject: **P1**
Location: **Otaniemi, Finland**
Date: **13.05.2019**

P1 is a physician and researcher that focus on chronic diseases related to gynaecology. The interview revealed the physicians' perspective about the experiences dealing with chronic diseases. These diseases can be avoided through prevention and having a healthy life. However, the main problem comes during the treatment phase because the treatment itself takes time; besides, patients are emotional and physical wear through all the process. When there is a mental health problem, the problem becomes critical because patients are depressed to continue with the treatment.

Chronic diseases often require a multidisciplinary team of specialist physicians to treat a patient. Something that has not been addressed is the internal networking of physicians because there is no way to know the expertise of each colleague. Besides, there is no way to know how their patients evaluate their physicians.

Related to communication, physicians and patients communicate using informal channels such as text messages or email; this represents a problem for data security. Furthermore, there is no channel to track patients outside the hospital until their next appointment.

In terms of waste, physicians are not aware of the amount of waste they generate in their work. Most of the products are designed for a single-use, mainly because they have a biological waste that represents a risk, and thus, they incinerate them.

Subject: **P2**
Location: **Otaniemi, Finland**
Date: **21.05.2019**

Subject P2 is a general physician, specialized in occupational diseases. This interview revealed more data about the challenges between the occupational and public sectors related to chronic diseases. While occupational services realize continuous patients' check-up, the public health sector is less efficient. The main reason is that physicians in the public sector are different each time a patient goes to a visit.

In Finland, mental diseases and illnesses related to genetics are increasing. Besides, the most vulnerable groups for chronic diseases are persons with addictions, mental health problems or work in jobs that involve hazards.

### PARAMEDIC

Person: **Marco Antonio Rico Cámara**
Location: **San Luis Potosí, México.**
Date: **03.10.2019**

Marco Antonio is a prehospital health care technician with eleven years of experience in the field. He has a certification for Basic Life Support (BLS) and Advanced Life Support (ALS). This interview gave information related to the experience related to the process from the paramedic unit perspective. The most relevant data is related to how to identify the symptoms of a cardiac arrest, the CPR correct procedure and their challenges, and the critical lapse time to help a patient. Besides, he highlighted the need for doing constant training to remember the CPR protocol, the need for the positive feedback and the pains of the AED devices.

### BYSTANDER

Subject: **B1**
Location: **Otaniemi, Finland.**
Date: **23.09.2019**

Subject B1 is a master student in Aalto working part-time as a designer in a multinational company. He did a CPR course during the military service seven years ago, but he has not any real experience after that training. The interview with this subject revealed that CPR training is not difficult. However, this person does not remember crucial information details related to CPR and AED devices. Besides, this person highlighted desirable experiences to encourage the user to use an AED during an emergency, the need for feedback after that emergency and the psychological support.

### FACILITY MANAGER

Person: **T.O.**
Location: **Otaniemi, Finland.**
Date: **26.09.2019**

T.O. works as a specialist in occupational safety in Aalto University since 2015. The person has a master of engineering related to environmental and biotechnology. This interview gave detailed insights from the facility manager perspective, related to the AED maintenance and CPR training for the building staff. The interview was not face-to-face, but the questions were answered in a digital document due to the tight interviewee schedule.

### 5.4 Insights

After analyzing the interviews' data, eleven insights related to the objectives have a potential opportunity for design concepts, considering services for CPR that can be integrated to the AED device and create more value for customers and end-users.

To understand better when and where they have more incidence during a cardiac arrest experience -before, during and after the emergency- a map that divides them between CPR and AED, and between circularity and usability help to locate them visually (figure 15). The majority of the insights are located 'during' the cardiac arrest moment performing CPR and using the AED; most of them aim to improve the interaction and increase the AED's value. The second bigger group is located 'before' the experience; those related to the training and patient's symptoms recognition. The third group of insights, 'after' the experience, includes what is valuable and meaningful for users about the experience they had through positive feedback/learning and opportunity cases for circularity.

The proposed insights are the ones that have a relation with circularity, products and services in a cardiac arrest situation. However, in the appendix at the end of this document, the interviews' summaries give more insights related to other problems that have a relation with the treatment of chronic diseases and the pains from physicians' perspective in the health system.

Image: CPR training kit during *restart a heart day* (Author's photograph).

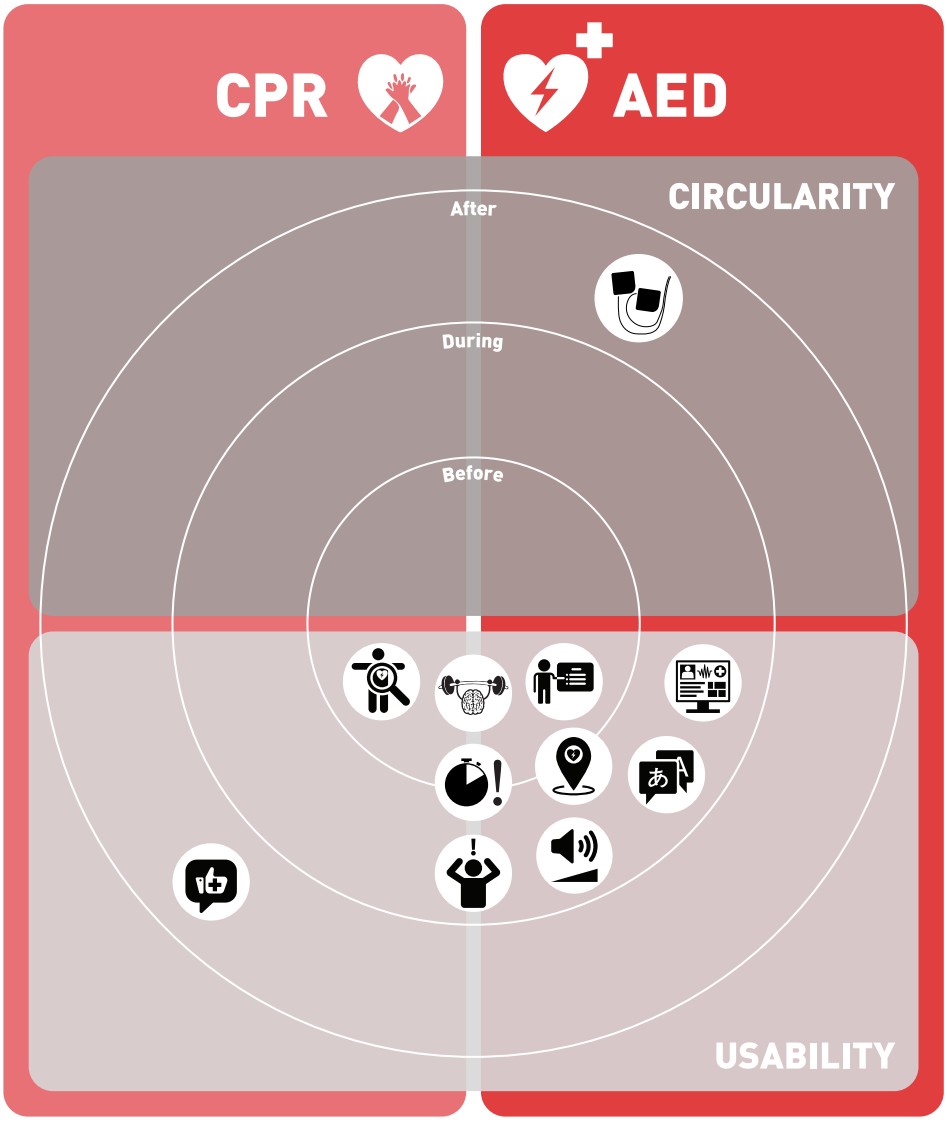
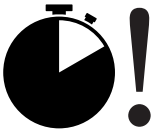



Figure 15: CPR and AED insights mapping (Diagram by the author).



**Time awareness**

The first 10 minutes after a heart stops beating is considered as a clinic death. This time is essential because, after that time, biological death starts and all the organs suffer severe damage. It is crucial to start immediately basic life support until the medical staff arrives or the patient revives during the first ten minutes. Time awareness is vital for paramedics and bystanders because they will know the remaining time that they have to reach the patient before the biological death threshold is reached.

**Patient's location**

The paramedic unit requires to know the precise location to reach the patient as soon as possible. The paramedic unit in the ambulance follows the directions from the emergency call centre to reach the emergency place. However, sometimes they are lost in the public space; including a GPS in the AED, could help them to locate the emergency place precisely. For instance, the web page 'Defi.fi', in which the AED devices location appear on a map, can be integrated to the emergency app '112 Suomi" to connect the devices and create more value sharing resources.

**Patient's data access**

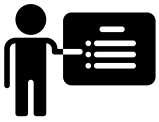
The patient's clinic history data can be useful for paramedics during the time commuting in the ambulance to be aware of the patient's former illnesses. Primary data as gender, age and clinic history are information that paramedic units desire. RFID technologies -such as microchip implants, tags or smartwatches- can share data with the AED device to share the information with the emergency unit if the device connects to the internet.

**Patient's symptoms recognition**

Bystanders often do not recognize the right symptoms during an emergency. This situation represents a problem from the emergency service because when a bystander calls, they need to know the patient's symptoms to send the ambulance with the right equipment. There is a need for solutions that helps bystanders to identify the patient's symptoms and know what to say when they call the emergency number. The app service '112 Suomi' has the potential to be a tool to train symptoms recognition.

**Human errors**

Bystanders sometimes make errors performing CPR or using the AED, such as not turning on the device, place the electrode pads in the wrong location or not applying pressure at the right place on the patient's chest. The interaction instructions must improve to decrease these errors.



**Customer's loyalty through training**

AED designs are different among suppliers. However, the function of the device is the same, and they have similar interactions. Persons who take a CPR course get familiar with the device they used; this means that a way to engage customers for a long term is to provide training to their staff with the same devices they have at the public space. Using the same device increase confidence in a real emergency.

**Positive feedback**

Paramedics and bystanders desire to receive positive feedback about how they performed the CPR and used the AED. After training or a real event, feedback on how can they improve will decrease the probability of errors in the future.

**Constant Training**

Facility managers and paramedics agree that constant training is the way to learn how to perform CPR accurately in a real situation; the main reason why it should be continuous is that when a real emergency happens, the mental stress affects the memory and usually the training is forgotten. Besides, practicing CPR during earlier stages of education was suggested, as well as during adulthood to increase the number of persons that can save a life.

**Electrode PAD upscaling**

The AED devices are reliable in their function. However, the electrode pads generate waste after their use or when their glue reaches the expiry date. The electrode pads sensors can be re-used; changing their product architecture to enable the adhesive to be replaced, keeping the reliability of its function, is an option to keep their value and make the component circular.

**Language Instructions**

Bystanders and paramedic highlighted that AED language instructions -coming from the speaker- become a challenge when the person who tries to use the device speaks another language (e.g., tourists). The language barrier requires a solution to communicate the instructions in a better way to avoid mistakes and interact with the device appropriately.

**Sound quality**

Public spaces are noisy. Some AED devices do not have a proper volume and audio quality to understand the instructions. In open areas, noise often is higher than the device's sound strength.

# 06
# DESIGN CONCEPTS

The insights generated by the interviews provided different ways to add value for stakeholders through new services and product improvements. From an AED manufacturer perspective, it requires to change the mindset and a strategy to shift into a PSS in circular economy models in three steps. First, the company needs to invest resources for services development that incorporate with their products; second, the company needs to improve the usability and interaction of their current products. Third, the company should change the linear value chain into circular, analyzing different models and their implications from different perspectives (Figure 16).

### 6.1 Service Opportunities

Considering mainly the insights from the usability area (Figure 14), the first step is to develop new services surrounding a cardiac arrest experience. For instance, Digia Oyj (2019) developed "112 Suomi" mobile application (App); its principal value is the live precise location data using mobile GPS. The precise location is critical for emergency response centre (ERC) to send an emergency unit when a person calls the number. Furthermore, the app is useful when someone is in a forest or places that are not accessible by car; thus, even if persons know that the emergency number is 112, calling through the app has more value just for the location data. This example created value for two stakeholders, bystanders and ERC department; new services should generate and connect value for more than one stakeholder. Thus, manufacturers of AED devices can design an emergency service exploring new options for emergencies and training; these create value for end-users and the emergency response centre (paramedics).

However, the service can include a visible chronometer to track the time since the call started, this raises awareness for the biological death threshold (10 minutes after clinical death) that is valuable for the paramedic unit. Besides, the service can include the location of AED devices integrating "defi.fi" map information. For the CPR procedure, a metronome backed up with visual instructions can create confidence for bystanders; this is valuable for them to apply compressions to the chest patient with the right rhythm.

The second area of opportunities focuses on training services. Incorporating training videos for symptoms recognition, CPR and AED training is valuable and meaningful for bystanders. These training can be programmed to remind them always when to watch them again, as well as next certification training available from the Red Cross or Länsi-Uusimaa Rescue Department, to increase confidence in their skills through constant training.

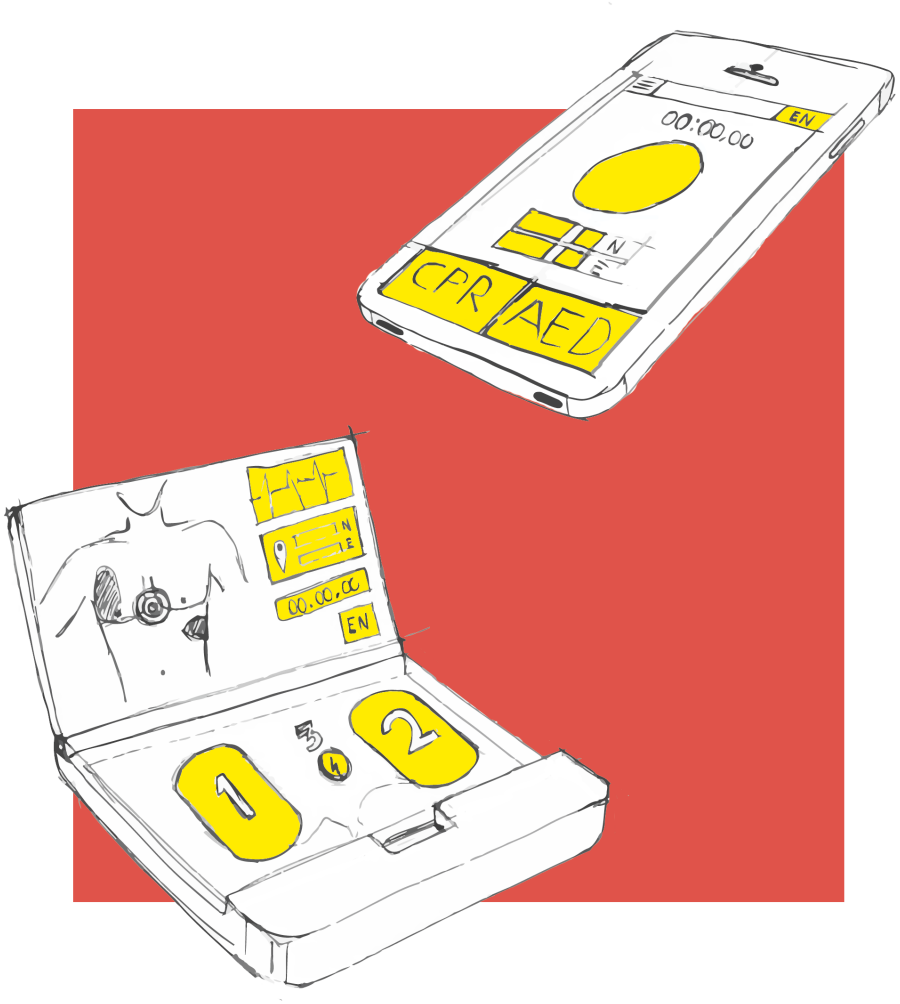



Figure 16: PSS Sketch concept (Sketch by the author).

Finally, the language barrier is something that should not be an impediment to save a life. These services must allow the option to select the preferred language of the user for instructions and training sessions. Enabling this option will reach more users, and thus, increase the value of the service.

### 6.2 Product Opportunities

The second step in the strategy is to improve the usability and interaction of the product. The AED devices are reliable in their use. However, human errors of interaction happen because the stress of the situation does not allow to think clearly, and the instructions of use are not clear enough for bystanders. The opportunities for improvement for AED devices, based on the insights, are the device location, the sequence of interaction, and the CPR procedure with the AED.

Concerning the first opportunity, the AED devices must have a GPS installed to be able to locate them precisely in public spaces. By Finnish law, all the devices must be registered at 'defi.fi' to know where they are located on the map; however, when paramedics arrive at the emergency place, in case they cannot track the bystander location through the mobile, the AED device can help to guide them.

Concerning the interaction, the device has only two buttons, turn on/off and shock. The main problem is the language barrier; the instructions given by the speaker in other language create stress to bystanders that do not understand the instructions. There are two ways to solve this problem, being able to select the language on the device or using a graphic user interface (GUI) that communicates the instructions visually.

In an ideal situation, two bystanders help the patient. One is performing the CPR, and the other brings the AED and connect the device. However, when the device starts analyzing the patient heartbeat, the AED should be able to track the compressions of the CPR and help the bystanders to follow the rhythm.

### 6.3 Circular Opportunities

Turning a product into a circular model requires to identify which value will be reintegrated to the chain and why. The insight for circularity that generates waste is the electrode pads that are disposed of after the emergency. As mentioned in chapter four, three circular models can be implemented for this case: product as a service, product life extension, and circular supply chain.

### Product as a service

Offering the AED device as a service implies that the manufacturer will keep the device ownership. Thus, the monitoring and maintenance of the AEDs will be the company's responsibility; the customer acquires them as a lease. The value for customers resides in delegating the maintenance, monitoring and reliability to the manufacturer; while the manufacturer can delegate activities to third parties to create result-oriented services (Tukker, A., 2004) to decrease the negative environmental impact.

From the manufacturer perspective, this implies new opportunities with key partners. The manufacturers can outsource suppliers as their touchpoints with customers and give them the exclusiveness of the product to them, in exchange for taking care of the distribution and maintenance. Besides, partnership with CPR training centres to promote its certification as part of the service will be more valuable for customers, offering a product as a service, with the services' opportunities mentioned before.

### Product life extension

This model is convenient for the electrode pads insight. These components usually are disposed of after use; to transform them into a circular model, they need to be restored in order to keep their value. This model implies that the electrodes' glue can be detached. The electrodes' sensors are valuable, a modification on the component's architecture to make it modular with a decouple interface, in relation with the glue, will extend the pads' life to be used more than one time. The manufacturer requires to collect the pads after their use or expiry date; then disassembly or detach the glue from the electrode pads, sterilize the pads, add the new glue to the electrode pads, assembly the component, and test it. This process (the task of collection, disassembly, repair and test) can be delegated to crucial partners or done directly by the manufacturer, and this decision requires to analyze which is the best option using the available resources that each company have.

### Circular supply chain

The circular supply chain model applies for AED devices in a "build to last" sub-model. In case a company decide to do a re-design of their products, this model helps to plan the product architecture; for AED devices, a modular slot or modular bus type will be convenient (Ulrich, K., 1995). These types of architectures enable the product to be upgraded and updated for future components and platforms. In this case, manufacturers require to analyze which components they will develop, and which ones will get from third party companies. The value of this model for manufacturers is to have standardized modular interfaces for assembling and disassembling processes. Furthermore, this model, combined with a "cradle to cradle" method, can analyze each component of the AED to reintegrate their value to the chain through sustainable processes and materials.

### 6.4 Design tool for PSS in circular models

Analyzing circular opportunities through different models gave the general conception of how a product's value can be reintegrated into the value chain. The strategy's implications suggested came from a personal design perspective and knowledge; however, more implications from business and technology perspectives are needed to be explored to validate a proposed circular model.

Different organizations provide tools to evaluate different aspects and stages for circular models. For instance, the circular design guide (2017) -a collaboration between Ellen MacArthur Foundation and IDEO- created methods for understand, define, make, and release stages; while other digital tools like the "circular pathfinder" (2017) developed by Resource Conservative Manufacturing foundation (ResCoM), suggest circular models based on the input data that users provide. However, most of the tools are designed to be used only by one person or organization and aims to analyze a product from only one perspective.

PSS in circular economy models requires the knowledge of different stakeholders. Therefore, a tool was designed to address transdisciplinary collaboration and helpt to analyze a PSS case in a teamwork format. The tool visualizes the case from business, design and technology perspectives, link the meanings of value among them, and visualizes all the implications of moving towards a circular model. This information is crucial to validate the proposed circular models.

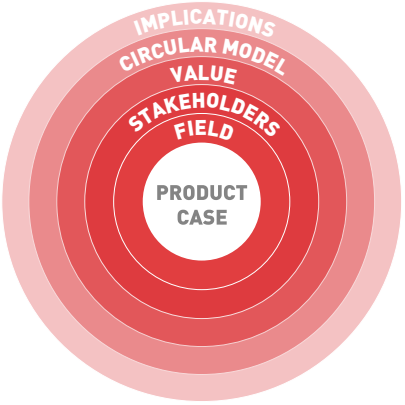



Figure 17: Rings structure (Diagram by the author).

Starting at the centre with the PSS case, its main structure is composed of five concentric rings, in which each ring contains a concept shared among the perspectives (Figure 17). The first ring identifies the expertise perspective. The second ring aims to identify the stakeholders that are involved in the case; it answers "who". The third ring helps to visualize what the stakeholders value and why, as well as identify which value can be recovered. The fourth ring aims to see which circular model can be used to recover a particular value. Finally, the fifth ring is to create awareness of all the implications, or milestones, of moving into a circular model. Furthermore, after finishing the content of each ring, the areas between perspectives aims for opportunities or ideas that are triggered, juxtaposing each perspectives' content.

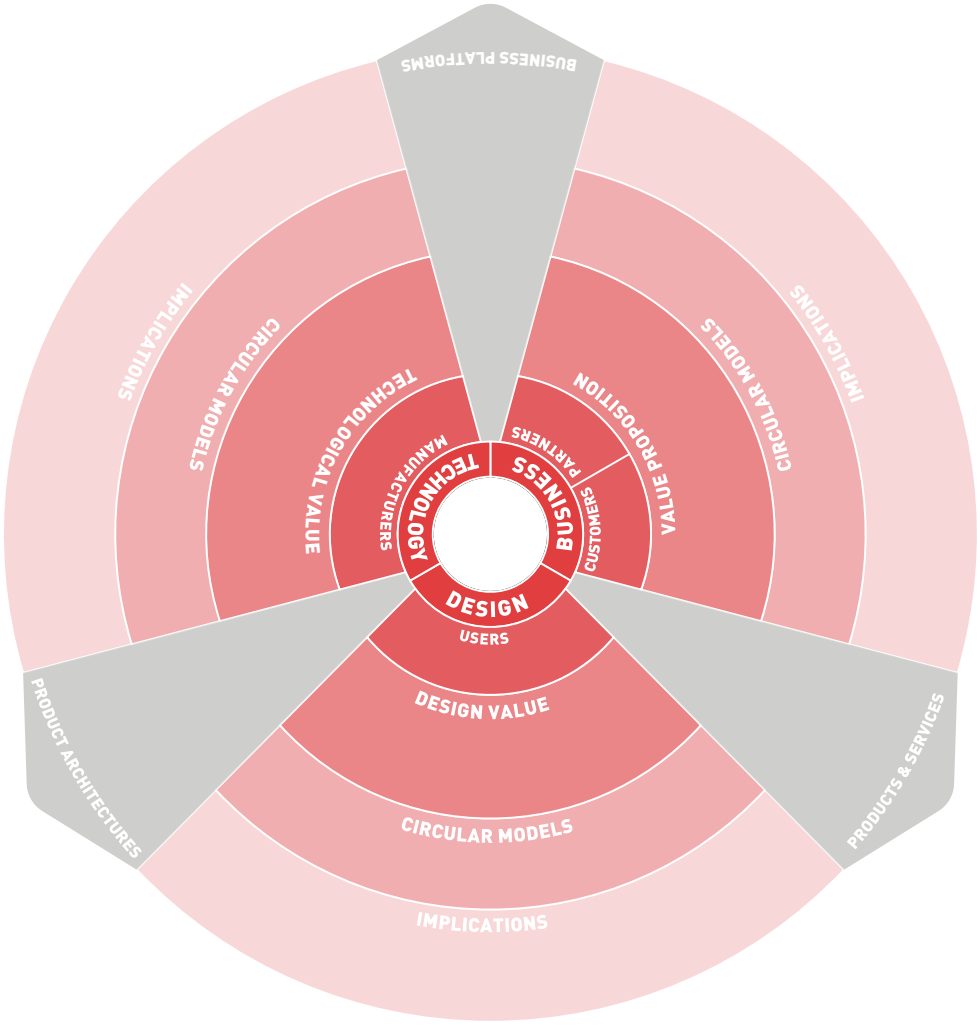



Figure 18: Tool's design proposal (Designed by the author).


Figure 19: Tool test during workshop (Author's photograph).

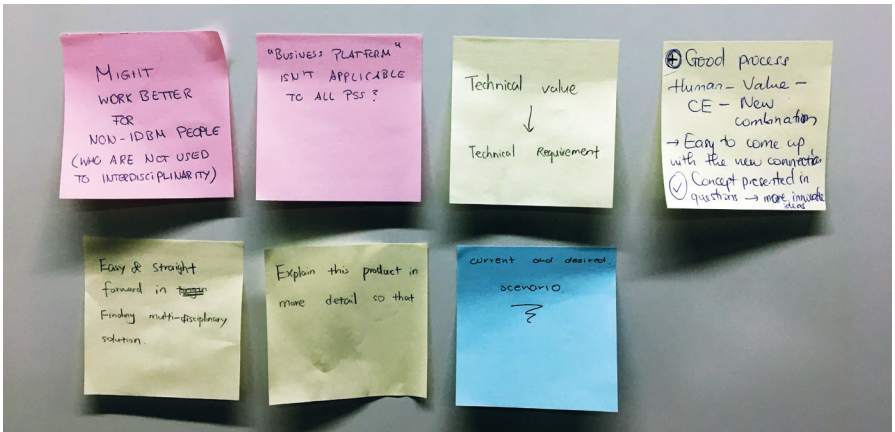
The tool proposal (Figure 18) helps with the implications, awareness and opportunities of moving a PSS into a circular model in a teamwork format and it has limitations regarding the revenues and costs, and key resources. The factors it addresses are the stakeholders in the ecosystem, the meaning of value for each of them and the co-creation opportunities. The tool requires basic knowledge on circular models, the participation of experts related to the case, and it has a more structured and intuitive design on how to fill the content on it.

The "circular business model canvas" (2019) developed by Circulab covers the revenues, key resources and distribution in a more detailed way. However, it does not separate the value for each stakeholder, and it does not profoundly contemplate the implications. The colour code it uses helps to identify the sections. However, the order about where to start filling the information is not clear, which only create confusion if no one has prior experience with the traditional business model canvas.

The "value chain canvas" (2019) also developed by Circulab covers the value in the whole chain; it is product-centred oriented and covers the opportunities within the chain. However, the design of the tool does not trigger interaction with the tool because it does not have further instructions or information about what information should be written in each segment of the canvas.

The tool was tested in a workshop (Figure 19) using the electrode pads as a case. The experts -master students from design, business and engineering schools- worked filling the data in their five rings first; then they switched places with other experts and explained their perspectives; finally, they interacted with their neighbours to identify opportunities. The overall experience and appreciation from the participants were positive; the interaction with the tool was fluid, organized and easy to use. At the end of the workshop, the participants gave feedback for a future iteration in the tool's design and test:

- Explain how the product work during the presentation.
- Write questions inside each ring that influence the type of answers desired.
- In the value section, visualize the product's current value and the new one in a circular model to compare them.



# 07
# CONCLUSIONS

## Conclusions

Answering the research question requires to explain the outcomes for each of the objectives. After a deep reflection, circular economy models complement the dimensions for product-service systems. The circular models link the value and lifecycle dimensions; while the HCD and the collaborative design approach links the user and ecosystem dimensions. In the context of healthcare, to design PSS that involves circular models, it requires a holistic view of the challenge, the full understanding of each dimension in the system, and how they affect each other.

Concerning the first thesis objective, the AED device was identified as a convenient product case to analyze and turn into a circular model, through the study case and HCD approaches. Circular models focus on the value of the product in their value chain; the design strategies of Bakker et al. (2018) using the "value" and "criticality" metrics were useful to validate the AED as a product that can be transformed into circular models. After validating the product, the next path was to understand why the product becomes waste and which components are disposed of; the types of obsolescence proposed by Hollander et al. (2017) helped to identify those components and the reasons of their disposal. Thus, identifying the value and obsolescence of a product is essential for circular models.

Concerning the second objective, the HCD approach using in-depth interviews revealed new design opportunities for products and services. However, not having access to a manufacturer interview reduced the number of insights for circularity. Something not expected in the study case is that the CPR procedure was critical in a cardiac arrest interacting with the AED device; while some insights created potential services opportunities around the CPR, others were related to improving the AED interaction. Thus, to transform a product into a product-service system, exploring services that complement the product could create new value. Furthermore, the access to manufacturers to get their expertise about the product is crucial for circular models, and to identify possible partnerships for services.

Concerning the third objective, due to the time limitation of the project, the tool was designed without experts but tested and evaluated by them in a collaborative workshop to receive feedback for a future iteration, using the electrode pads as a test case. The tool was designed to analyze the case from a holistic perspective, understanding the same case from the perspectives of design, business and technology. During the test workshop, introducing the topics of circular models and PSS helped the audience to understand the objectives. However, to trigger more ideas in a future workshop, doing a "teardown" activity of the product, or having an image with an explosive view of all the components will help to analyze the product architecture.

Alongside the contribution of the tool, the challenge in designing tools with a holistic

view is its transdisciplinarity behaviour. However, the collaborative approach used during a testing and evaluation stages generates insights to improve a tools' design, when a transdisciplinary creation is not possible. From the design perspective, designing these type of tools without other disciplines involved implies that the designer should understand other perspectives; the limitation resides in the knowledge that the designer has about the topics that the tool will address.

The design approaches give methods that help us in our work to get the material that we require, based on a particular perspective. However, as new design approaches emerge for complex design challenges, the designer requires to go beyond the design field and expand its knowledge to address such problems. Furthermore, as disciplines start to cross the boundaries of their fields, new approaches and tools for transdisciplinary processes need to be developed. It implies decentralizing one perspective in an approach and considering other perspectives simultaneously, in a holistic mindset, matching common grounds and understanding the meanings of a concept.

For instance, the human-centred design has a perspective that focuses on humans' factors and usability to address user needs; it has been a reliable approach for the design field. In the other extreme, circular economy models are product-centred, they analyze the value chain of a product through the drivers of customer-centricity, technology and sustainability; the circular models and sub-models provide strategies on how to keep value and decrease waste. Product-service systems expand the view because they integrate the user cycle (from design field), the value proposition of a product (related to business model design), the offering lifecycle of a product (the value chain), and the ecosystem (stakeholders) as an integrated entity. Systems go beyond approaches because they are holistic.

The limitations of creating transdisciplinary approaches and tools reside in how they are created. They must be created in collaboration with other disciplines; thus, to co-create transdisciplinary solutions, the creators' knowledge must be broad in their field, and if possible, other fields of knowledge. Another limitation is the access of real cases; systems involves a high number of factors and stakeholders; the access to them is crucial to test, iterate and validate the outcomes.

For the academy, developing those approaches and methods will create value for the industry. Recently, companies look for employees that have competence in more than one field; they are more valuable for them because they are versatile. The same situation happens for design tools; the problems we try to address with them demands more knowledge from other fields to be used in different contexts. Thus, developing tools for transdisciplinary work should be analyzed, explored and developed for complex multidimensional systems.

# REFERENCES

## REFERENCES

American Heart Association. (2019). About Cardiac Arrest. Retrieved from: https://www.heart.org/en/health-topics/cardiac-arrest/about-cardiac-arrest [Accessed on 15 August 2019].

American Heart Association. (2019). Out-of-hospital Chain of Survival. Retrieved from: https://cpr.heart.org/AHAECC/CPRAndECC/AboutCPRFirstAid/CPRFactsAndStats/UCM_475731_Out-of-hospital-Chain-of-Survival.jsp [Accessed on 15 August 2019].

Arponen, J. Juvonen, L. (2017). Circular economy business models for the manufacturing industry. Circular Economy Playbook for Finnish SME's. Retrieved from: http://www.kasvuakiertotaloudesta.fi/ [Accessed on 30 December 2018].

Amit, R., Zott, C. (2015). 'Creating Value Through Business Model Innovation'. MIT Sloan Mangement Review – Top 10 Lessons on Strategy. [Online]. 36 - 44

Cambridge University Press. (2019). Cambridge Dictionary – Meaning of health in English. Available from: https://dictionary.cambridge.org/dictionary/english/health [Accessed on 10 January 2019].

Castillo-Montoya, M. (2016). Preparing for Interview Research: The Interview Protocol Refinement Framework.The Qualitative Report, 21(5), 811-831. Retrieved from: https://nsuworks.nova.edu/tqr/vol21/iss5/2

Charter, M. (2019). 'Circular Economy innovation and design – Setting the scene'. In: Charter, M. (ed.) Designing for the Circular Economy. New York: Routledge. pp. 23-34.

Charter, M., McLanaghan, S. (2019). 'Business models for a Circular Economy'. In: Charter, M. (ed.) Designing for the Circular Economy. New York: Routledge. pp. 89-101.

CHRODIS PLUS joint Action. (2018). A-CHRODIS - Addressing Chronic Diseases and Healthy Ageing across the Life Cycle. Available from: http://chrodis.eu/ [Accessed on 05 January 2019].

Circulab. (2019). Circular toolbox. Retrieved from: https://circulab.com/toolbox-circular-economy/ [Accessed on 23 October 2019].

Digia Oyj. (2019). 112 Suomi. Available from: https://digia.com/en/112-suomi/

Ellen MacArthur Foundation. (2017). The Circular Design Guide. Retrieved from: https://www.circulardesignguide.com/ [Accessed on 23 October 2019].

Health Capital Helsinki. (2018). Why Health Capital Helsinki?. Available from: https://www.healthcapitalhelsinki.fi/en/quick-facts/ [Accessed on 30 December 2018].

Hollander, M. C., Bakker, C. A. and Hultink, E. J. (2017), Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms. Journal of Industrial Ecology, 21: 517-525. doi:10.1111/jiec.12610

Institute for Health Metrics and Evaluation. (2018). Finland. Available from: http://www.healthdata.org/finland [Accessed on 12 August 2019].

International Liaison Committee on Resuscitation. (2008). ILCOR presents a universal AED sign. Retrieved from: https://www.ilcor.org/news/news-archive/ilcor-presents-a-universal-aed-sign [Accessed on 21 August 2019].

INUSE Research Group. (2017). Co-Design Journey Planner. Retrieved from: http://codesign.inuse.fi/ [Accessed on 30 December 2018].

ISO. (2010). ISO 9241-210. Ergonomics of human-system interaction. Part 210: Human-centred design for interactive systems. Switzerland: ISO copyright office.

Kane, G., Bakker, C. & Balkenende, A. (2018). Towards design strategies for circular medical products. Resources, Conservation & Recycling, 135(C), pp. 38-47. doi:10.1016/j.resconrec.2017.07.030

'Life-savers out of time' (2017, 24 Jul.) Henley Standard. Retrieved from: https://www.henleystandard.co.uk/news/henley-on-thames/113133/life-saversout-of-date.html [Accesed on 16 August 2019].

Mannonen, P., Kaipio, J., & Nieminen, M. P. (2017). Patient-centred design of healthcare services: Meaningful events as basis for patient experiences of families. In Building Capacity for Health Informatics in the Future (pp. 206-210). (Studies in Health Technology and Informatics; Vol. 234).

McAloone, T., Pigosso, D. (2019). 'Designing Product Service Systems for a Circular Economy'. In: Charter, M. (ed.) Designing for the Circular Economy. New York: Routledge. pp. 102-112

Muratovski, G. (2016). Research for Designers. A guide to methods and practice. London, England: SAGE.

National Heart, Lung, and Blood Insitute NHLBI. (2019). Defibrillators. Retrieved from: https://www.nhlbi.nih.gov/health-topics/defibrillators [Accessed on 15 August 2019].

National Institute for Health and Welfare. (2019). Chronic Diseases – General Information. Retrieved from: https://thl.fi/en/web/chronic-diseases/general-information-about-chronic-diseases-affecting-public-health [Accessed on 05 January 2019].

Needpix. (2019). Semi-Automatic Aed Defibrilator Free Picture. [Image]. Available from: https://www.needpix.com/photo/608985/semi-automatic-aed-defibrillator-protection-heart-attack-cardiac-arrest-user-friendly-orange-white [Accessed on 16 August 2019]

OECD Better Life Index. (2018). Finland. Retrieved from: http://www.oecdbetterlifeindex.org/countries/finland/ [Accessed on 2 January 2019].

Resource Conservative Manufacturing (2017). The ResCoM platform and tools. Retrieved from: https://www.rescoms.eu/platform-and-tools [Accessed on 23 October 2019].

Servicia Medical. (2018). Defibrillaattori. Available from: http://www.defibrillaattori.com/defibrillaattori/ [Accessed on 14 August 2019].

Technische Hogeschool Delft & Boeijen, A. v. (2013). Delft design guide: Design methods. Amsterdam: BIS Piblishers.

Tukker, A. (2004). Eight types of product–service system: Eight ways to sustainability? Experiences from SusProNet. Business Strategy and the Environment, 13(4), pp. 246-260. doi:10.1002/bse.414

Ulrich, K. (1995). The role of product architecture in the manufacturing firm. Research Policy, 24(3), pp. 419-440. doi:10.1016/0048-7333(94)00775-3

Vezzoli, C. Kohtala, C. Srinivasa, A. et. al. (2014). Product-Service System Design for Sustainability. UK: Greenleaf Publishing Limited

Voudrias, E. A. (2018). Healthcare waste management from the point of view of circular economy. Waste Management, 75, pp. 1-2. doi:10.1016/j.wasman.2018.04.020

World Health Organization (2018). Noncommunicable Diseases (NCD) Country Profiles – FINLAND. Retrieved from: https://www.who.int/nmh/countries/fin_en.pdf?ua=1 [Accessed on 12 August 2019].

# APPENDIX

Interviews' findings
Interviews protocols
Interview consent form

# Interviews' Findings

**Physicians**

"P1"

- Chronic diseases require a multidisciplinary team, but physicians do not meet directly to treat a disease, which makes the treatment process slow.
- The internal network of physicians is something that can be improved because physicians do not know the specific expertise of each colleague on the list. There is no feedback system, from patients to physicians, to suggest which ones are better for a specific case.
- Chronic diseases can be avoided through prevention and living a healthy life.
- People who are more educated usually invest in prevention.
- The most common chronic diseases are obesity, diabetes, alcoholism, heart diseases in Finland. However, all of them have the same level of urgency.
- Pain is a symptom; it is related to mental health, and sometimes to other diseases. It needs to be addressed as a possible disease because some patients develop an addiction for them.
- Mental health problems are a challenge when they are present with other diseases because depression affects treatment. The motivation of patients is essential to deal with chronic diseases
- The pains of dealing with chronic diseases are that they take a long time to recover or control; patients are tired mentally and physically to take care of their health.
- Sometimes it will be desired that all the specialist physicians can treat a patient on the same day instead of multiple appointments on different days.
- Monitoring the patient is formal in the hospital visit, but it is informal to communicate when they are outside the hospital because patients use text messages or emails to communicate with their physicians. The data is not secure using those channels.
- Physicians are not aware of what generates waste, but there are products that are single-use and then disposed of to the trash bin.
- Most of the products with biological waste are incinerated because they represent a risk for infections.

**Physicians**

"P2"

- The main targets for occupational health are the prevention of diseases, early diagnosis and early treatment.
- In Finland, chronic diseases have dramatically decreased, such as breast cancer, pulmonary diseases, heart conditions and others due to occupational health.
- In Finland, allergies, immunity and infectious diseases are increasing due to genetic problems. Mental diseases are increasing too.
- In Finland, patients using occupational health services or that have private insurance, have proper health prevention and treatment. However, those who use the public health system service is slower because the waiting list is long.
- The problem of chronic diseases is the follow up of patients in the public sector because the doctor is different in each visit; they need to read all the clinical history of the patient every time.
- The most vulnerable groups in Finland are patients suffering from addictions, then persons with mental problems and finally, patients with occupations that deal with hazards.
- Patients with addictions are the most difficult because they sometimes lie, try to manipulate the tests and do not follow the treatment.
- Constant check-up will decrease the possibility of developing chronic diseases.

**Paramedic**

Marco Antonio

Findings:

- Bystanders do not recognise the difference between a cardiac arrest and a heart attack.
- The symptoms for a cardiac arrest are easy to identify: loss of consciousness, stop breathing and no pulse.
- The critical moment is during the first ten minutes. During that time, a person is clinical death. After 10 min, biological death starts and has severe consequences for the organs.
- CPR is basic life support. The process requires 30 compressions, then two ventilations and repeat the process five times. The process must continue until the paramedic unit arrives.
- The body posture during CPR is something that people often do wrong.
- The AED stops the hearth to correct the rhythm and the CPR reanimate it.
- The emergency call is essential, in terms of when someone needs to call and what information the emergency call centre receives to send the ambulance with the right equipment.
- The person who calls the emergency number should be the last to end the call. That person can receive support from the call to help a patient while the paramedics arrive at the place.
- 70% of the calls are different from what the patients had because bystanders do not recognise the symptoms.
- CPR training should be taught since the primary education level.
- The ambulance only receives the address to reach the emergency location, but there is no way to know precisely where in the public space is the patient's location.
- A person suffering a cardiac arrest must be revived at the place. The ambulance does not take the patient to the hospital because that person is "dead" (clinical death). Until the patient revives, they take them to the hospital. If another cardiac arrest happens in the ambulance, they proceed with CPR while they commute to the Hospital.
- Bystanders do not turn on the device; they only stick on the PADs.
- People need constant capacitation; they forget everything due to the stress of the situation.
- Bystanders do not stick the pads on the right location or do the compressions on

the right location.

- Paramedics are not aware of how the PADs are disposed.
- Paramedic units will value to have the patient's age and clinic history in advance.
- Paramedic units will value to track the exact laps of time since the emergency happened.
- The most valuable situation is when someone starts the CPR instead of waiting for the ambulance to begin the procedure.
- The user recognizes that positive feedback about their performance is always valuable and desirable.
- GPS in AED devices is desirable.
- AED language instructions should be in the language of the bystander.
- AED speakers quality sometimes is terrible or the volume is not enough to be heard at public spaces.

**Bystanders**

"B1"

Findings:

- The subject does not know the difference between a cardiac arrest and a heart attack.
- It is difficult to know if a person has a cardiac arrest if we do not understand its symptoms.
- The subject knows that there are defibrillators in public spaces, but not exactly where, just remembered the signs.
- The CPR procedure is not complicated, 30 pushes and then breathing twice, but the rhythm of the pushes is challenging to remember.
- The challenging training with CPR is that it is not a real person; it is a doll, which means that the stress level is different.
- During the training, the subject did not try the defibrillator. The instructor only showed the device and the necessary instructions on how to use it without using it directly.
- The subject remembers that the AED device gives the instructions through its speaker.
- The subject does not remember where exactly the electrode pads location on a person's chest.
- In a stress situation, the subject will not remember everything he learned at his training.
- It is desirable to have a person to talk to after a cardiac arrest situation.
- After the emergency, the subject wished someone who gives feedback about the CPR procedure to correct and improve how the subject performed.
- The subject values to have someone to talk and listen to him after the event.
- This person wishes to have all the equipment required is in place and dare to try out the devices without hesitation.
- This person prefers a conversation than following a voice command from the AED device.
- The subject did not take the CPR course to renew the licence after seven years.
- The language of the defibrillator is useless if the bystander language is different.

.

**Facility Manager**

Tiina Okkonen

Findings:

- The AED devices were selected using the same supplier as the university used before due to their easy use and maintenance, which means that the building management is loyal to the supplier.
- The AED devices registered are in defi.fi. In the page, a map appears with their location and availability.
- Occupational safety (company) and lobby services monitor the devices. Lobby services do maintenance every month and the supplier every five years or earlier if needed.
- The value of the AED devices selected for the building is that the occupational safety (service company) uses similar devices during the training sessions and that they guaranty to train the staff that the law request, which is 5% of office staff and 20% of workshop staff.
- The university offers ten courses for CPR per year.
- Everyone has access to the AED device.
- The staff must follow the instructions for an emergency, one staff begin with the first-aid, and the second one gets the AED device.
- After an emergency, the task from the facility manager side is to ensure the patient status and contact the supplier for the device's maintenance.
- The investment of all AED devices in Aalto is around 3000e for maintenance.
- Nonstop training videos is a desire to increase the capacitation for CPR and AED.
- The language of the AED devices should also be in English.

.

# Interviews Research Protocols

# INTERVIEW RESEARCH PROTOCOL

## PHYSICIANS

**Aalto University**

**Master program in Collaborative and Industrial Design**

**Manuel Rosales**

***Interview objective:***

The purpose of this in-depth interview is to understand the experiences and challenges from physicians' perspective about chronical diseases and find insights related to the topic.

***Research objectives:***

1. To find potential future concepts for products, services and/or service-product systems for healthcare that could be designed in circular economy models in Finland, considering chronic diseases as a study case to improve well-being and decrease waste and resources consumption.
2. To define design concepts in collaboration with medical staff, experts and/or patients.

***Main research question:***

*How might we design products, services and/or product-service systems in circular economy models through a collaborative design approach for chronic diseases?*

***Interviewees persona's profile***

General physicians or specialist physicians with experience in diagnosing, treatment and/or monitoring chronic diseases in Finland.

# INTERVIEW PROTOCOL

**Script before the interview:**

*I'd like to thank you once again for being willing to participate in the interview aspect of my study. As I have mentioned to you before, my research seeks to understand how the process between patients and physicians is done related to chronic diseases and the challenges related to them for prevention, monitoring and treatment. The study also seeks to understand how the impact of chronic diseases on sustainability could be reduced by applying circular economy models. The aim of this research is to find insights for new design solutions for chronic diseases in circular economy models through collaborative design.*
*Our interview today will last approximately one hour during which I will be asking you about your process' experiences with patients dealing with chronic diseases, the challenges from your perspective related to them and their impact on sustainability.*

[review aspects of consent form]

*Before starting the interview, you completed a consent form indicating that I have your permission (or not) to audio record our conversation.*
*Are you still ok with me recording (or not) our conversation today? ___Yes ___No*

*If yes: Thank you! Please let me know if at any point you want me to turn off the recorder or keep something you said off the record.*
*If no: Thank you for letting me know. I will only take notes of our conversation.*

*Before we begin the interview, do you have any questions? [Discuss issues]*
*If any questions (or other questions) arise at any point in this study, you can feel free to ask them at any time. I would be more than happy to answer your questions.*

**Introductory Questions**

*Thank you for participating in this interview, for the beginning I'd like to ask you about yourself, your professional background and the general implications around chronic diseases.*

1. *Can you introduce yourself briefly? Name, professional background, specialisation, current work and years of experience.*
2. *What inspires you every day in your work?*
3. *How do you define chronic diseases?*
4. *What caused chronic diseases to be a trend in our current time?*
5. *Among all the chronic diseases, which ones do you consider, are more common in Finland? Why?*

**Transition Questions**

*Thank you for your responses. I'd like to ask you now questions regarding your experiences dealing with chronic diseases and patients.*

1. *Which are your experiences during the treatment stage for chronic diseases?*
2. *Which are the challenges or pains that patients have to deal with chronic diseases?*
3. *Which are the challenges for physicians dealing with chronic diseases?*
4. *How do you monitor the progress of your patients?*
5. *What problems do you often have during monitoring and/or treatment process of chronic diseases?*
6. *Which are the risks for patients during the treatment process of chronic diseases?*

**Key Questions**

*Thank you for your responses. I'd like to ask you now questions about treatment, monitoring and sustainable impact of chronic diseases.*

7. *During the treatment of _____, which services and products do you and your patients requires during the process? Why?*
8. *What will you wish to have, or which will be the ideal solution to monitor and treat your patients?*
9. *Which medical products generate more waste during the treatment of chronic diseases?*
10. *How do you dispose of them? Are they sanitised and recycled or reuse?*
11. *When do you upgrade your medical equipment? Why?*

***Closing Questions***

*Thank you for your responses. To finish this interview, I'd like to ask you now questions about the prevention of chronic diseases.*

12. *What is your advice to prevent chronic diseases?*
13. *Which 3 chronic diseases do you think are the most urgent ones that need to be solved in Finland?*
14. *Would you want to say or add something else about any of the topics during the interview?*

# INTERVIEW RESEARCH PROTOCOL

## BYSTANDERS

**Aalto University**

**Master program in Collaborative and Industrial Design**

**Manuel Rosales**

***Interview objective:***

The purpose of this in-depth interview is to understand the experiences they bystanders had in a public space with a person under a cardiac arrest. Also, persons who have basic training in performing cardiopulmonary resuscitation (CPR) and/or interaction with automated external defibrillators.

***Research objectives:***

1. To find potential future concepts for products, services and/or service-product systems for healthcare that could be designed in circular economy models in Finland, considering chronic diseases as a study case to improve well-being and decrease waste and resources consumption.
2. To define design concepts in collaboration with medical staff, experts and/or patients.

***Main research question:***

*How might we design products, services and/or product-service systems in circular economy models through a collaborative design approach for chronic diseases?*

***Interviewees persona's profile***

Adults who have a former experience helping a person with a cardiac arrest or that has basic training on CPR.

# INTERVIEW PROTOCOL

**Script prior to the interview:**

*I'd like to thank you once again for being willing to participate in the interview aspect of my study. As I have mentioned to you before, my study seeks to understand the experiences of bystanders/persons in relation to cardiac arrests and the use of automated external defibrillators (AED). The study also seeks to design concepts in circular economy models for AED devices through a collaborative design approach.*
*Our interview today will last approximately one hour during which I will be asking you about your experiences with patients dealing with cardiac arrest, the challenges and implications their impact on sustainability.*

[review aspects of consent form]

*Before starting the interview, you completed a consent form indicating that I have your permission (or not) to audio record our conversation.*
*Are you still ok with me recording (or not) our conversation today? ___Yes ___No*

*<u>If yes</u>: Thank you! Please let me know if at any point you want me to turn off the recorder or keep something you said off the record.*
*<u>If no</u>: Thank you for letting me know. I will only take notes of our conversation.*

*Before we begin the interview, do you have any questions? [Discuss questions]*
*If any questions (or other questions) arise at any point in this study, you can feel free to ask them at any time. I would be more than happy to answer your questions.*

**Introductory Questions**

*Thank you to participate in this interview, to begin I'd like to ask you about yourself, your professional background and the general implications about cardiac arrests.*

1. *Can you introduce yourself briefly? Name, professional background, current work and years of experience.*
2. *What inspires you every day in your work?*
3. *Do you know what is a cardiac arrest? (If no, explain. If yes continue to next question).*
4. *How do you define a cardiac arrest?*
5. *Have you helped or seen a person having a cardiac arrest? (If yes, continue to next question. If no, go to next section).*
6. *Can you describe the story or experience you have in that situation?*

**Transition Questions**

*Thank you for your responses. I'd like to now ask you questions regarding your experiences dealing with chronic heart diseases.*

7. *Do you have any relatives or known person with an ischemic or heart disease? (If yes, continue to next question. If not, continue to next question)*
8. *Can you tell which are the challenges that your relative/person have to deal with that disease?*

**Key Questions**

*Thank you for your responses. I'd like to now ask you questions about the process to treat a cardiac arrest before, during and after the experience.*

*BEFORE*

9. *What will you do if you see a person that needs help suffering a cardiac arrest? Can you describe the steps that you will do?*
10. Do you know what an external defibrillator is?
11. Do you know the location of the external defibrillators in public spaces? Have you seen them before in buildings? Where?

*DURING*

12. *Do you know what is CPR? If yes, Do you know how it is done? (if yes, go to next question).*
13. Can you explain how to do a CPR procedure correctly?
14. Which are the challenges or pains of doing a CPR?

15. Have you used or know how to use an automated external defibrillator? (If yes, continue to next question. If not, continue to question 17)
16. Can you explain how it is used?
17. Can you describe the general experience of performing a CPR and/or using a defibrillator?
18. Which is the most critical stage or task during the CPR? Which are the difficulties?
19. What would you expect that an automated defibrillator will do to help a person in a cardiac arrest? How?

*AFTER*

Only they have the experience.

20. When the paramedic unit arrives, which is the first thing they asked you? Or how do you start the interaction with them? Can you describe the experience?
21. After they take care of the patient, did they offered you any help? or aked about your emotional condition?
22. How did you feel after that experience during the next days?
23. What do you think could be improved during this situation related to the CPR, AED or interaction with paramedics?

***Closing Questions***

*Thank you for your responses. To finish this interview, I'd like to now ask you questions about how this experience can be less traumatic or stressed.*

24. What would you wish that could help you to decrease the stress or trauma of this experience?
25. *What would you value the most after this experience?*
26. *If you wish 3 things that AED devices could do for you, what would you wish?*
27. *Would you want to say or add something else about any of the questions during the interview?*

# INTERVIEW RESEARCH PROTOCOL

## FACILITY MANAGER

**Aalto University**

**Master program in Collaborative and Industrial Design**

**Manuel Rosales**

***Interview objective:***

The purpose of this in-depth interview is to understand the point of view of Automated External Defibrillators (AED) from a facility manager of a public space perspective, related to their maintenance and reliability.

***Research objectives:***

1. To find potential future concepts for products, services and/or service-product systems for healthcare that could be designed in circular economy models in Finland, considering ischemic heart disease as a study case to improve well-being and decrease waste and resources consumption.
2. To define design concepts in collaboration with medical staff, experts and/or patients.

***Main research question:***

*How might we design products, services and/or product-service systems in circular economy models through a collaborative design approach for chronic diseases?*

***Interviewees persona's profile***

*Facility managers of public spaces or employees in charge of AED devices.*

# INTERVIEW PROTOCOL

**Script prior to the interview:**

*I'd like to thank you once again for being willing to participate in the interview aspect of my study. As I have mentioned to you before, my study seeks to understand the point of view of facility managers in relation to AED devices and their maintenance and management. The study also seeks to generate design concepts in circular economy models for AED devices through a collaborative design approach.*
*Our interview today will last approximately one hour during which I will be asking you about your experiences with patients dealing with cardiac arrest, the challenges and implications their impact on sustainability.*

[review aspects of consent form]

*Before starting the interview, you completed a consent form indicating that I have your permission (or not) to audio record our conversation.*
*Are you still ok with me recording (or not) our conversation today? ___Yes ___No*

*If yes: Thank you! Please let me know if at any point you want me to turn off the recorder or keep something you said off the record.*
*If no: Thank you for letting me know. I will only take notes of our conversation.*

*Before we begin the interview, do you have any questions? [Discuss questions]*
*If any questions (or other questions) arise at any point in this study, you can feel free to ask them at any time. I would be more than happy to answer your questions.*

**Introductory Questions**

*Thank you to participate in this interview, to begin I'd like to ask you about yourself, your professional background.*

1. Can you introduce yourself briefly? Name, professional background, current work and years of experience.
2. What inspires you every day in your work?
3. What do you value in your daily work?

**Transition Questions**

*Thank you for your responses. I'd like to now ask you questions regarding the AED devices you have.*

4. How did you select the AED devices for the building?
5. Which services or benefits do you have with your AED supplier?
6. Which is the value of the AED devices and/or supplier that you selected?
7. Who is in charge of monitoring the AED devices?
8. Where are located and why?

**Key Questions**

*Thank you for your responses. I'd like to now ask you questions about your experience process whit AED devices during an emergency.*

*BEFORE*

9. Is there any protocol that the staff in the building must follow if there is a person in a cardiac arrest emergency?
10. How many persons in the staff know the procedure if it happens?
11. How many persons in the staff know how to do CPR?
12. Do you request CPR training for your staff? Why? How often?
13. Who has access to the AED during an emergency*?*
14. Which is your responsibility when you're notified about this situation?

*DURING*

15. When you are notified about the emergency, what do you do?

*AFTER*

16. After the emergency event, which are your tasks?

17. What do you do with the AED after the emergency?

***Closing Questions***

*Thank you for your responses. To finish this interview, I'd like to now ask you questions about the maintenance of AED devices.*

18. How often do you or the supplier come to check the devices?
19. How often do you change the batteries or the electrode pads?
20. How much do you invest per year for these devices?
21. Is there any service that you wish the supplier can offer to you?
22. If you have 3 wishes, what would you wish that the supplier or AED device could do?
23. Which will be the benefit for you to acquire the AED as a service instead of buying the product?
24. Would you want to say or add something else about any of the questions during the interview?

# INTERVIEW RESEARCH PROTOCOL

## PARAMEDICS

**Aalto University**

**Master program in Collaborative and Industrial Design**

**Manuel Rosales**

***Interview objective:***

The purpose of this in-depth interview is to understand the experiences from the emergency medical services -paramedics- in relation with cardiac arrests, basic life support and automated external defibrillators.

***Research objectives:***

1. To find potential future concepts for products, services and/or service-product systems for healthcare that could be designed in circular economy models in Finland, considering chronic diseases as a study case to improve well-being and decrease waste and resources consumption.
2. To define design concepts in collaboration with medical staff, experts and/or patients.

***Main research question:***

*How might we design products, services and/or product-service systems in circular economy models through a collaborative design approach for chronic diseases?*

***Interviewees persona's profile***

Active Emergency Medical Services (paramedics) with experience or advanced training for cardiac arrest treatment.

# INTERVIEW PROTOCOL

**Script prior to the interview:**

*I'd like to thank you once again for being willing to participate in the interview aspect of my study. As I have mentioned to you before, my study seeks to understand the experiences and process of emergency medical services in relation to cardiac arrests and the use of automated external defibrillators (AED). The study also seeks to design concepts in circular economy models for AED devices through a collaborative design approach.*

*Our interview today will last approximately one hour during which I will be asking you about your experiences with patients dealing with cardiac arrest, the challenges and implications their impact on sustainability.*

[review aspects of consent form]

*Before starting the interview, you completed a consent form indicating that I have your permission (or not) to audio record our conversation.*

*Are you still ok with me recording (or not) our conversation today? ___Yes ___No*

*<u>If yes</u>: Thank you! Please let me know if at any point you want me to turn off the recorder or keep something you said off the record.*

*<u>If no</u>: Thank you for letting me know. I will only take notes of our conversation.*

*Before we begin the interview, do you have any questions? [Discuss questions]*

*If any questions (or other questions) arise at any point in this study, you can feel free to ask them at any time. I would be more than happy to answer your questions.*

**Introductory Questions**

*Thank you to participate in this interview, to begin I'd like to ask you about yourself, your professional background and the general implications about cardiac arrests.*

1. *Can you introduce yourself briefly? Name, professional background, specialization, current work and years of experience.*
2. *What inspires you every day in your work?*
3. *How do you define a cardiac arrest?*
4. *Who is the most vulnerable sector for this complication?*
5. *How do you identify the symptoms in a person that is having a cardiac arrest?*

**Transition Questions**

*Thank you for your responses. I'd like to now ask you questions regarding your experiences dealing with chronic diseases and patients.*

6. *Which is the more critical moment during a cardiac arrest?*
7. *Which information and/or equipment is valuable for you in this scenario?*

**Key Questions**

*Thank you for your responses. I'd like to now ask you questions about the process to treat a cardiac arrest before, during and after.*

*BEFORE*

8. Can you tell me how the process is after you receive an emergency call? Which is the protocol you follow before you move the ambulance?
9. What do you do while you travel in the ambulance?

*DURING*

10. What is the first thing you do when you reach the patient?
11. How do you retrieve the patient's information?
12. Which patient's information is relevant for the paramedic unit?
13. Which are the more common mistakes that bystanders do while using the AED DEVICE and/or performing a CPR process?
14. Who is the most suitable person to manipulate an AED? Why?
15. How reliable are the automated external defibrillators? Why?
16. Which are the main problems or difficulties of these devices?

*AFTER*

17. How do you transfer the patient to the emergency department? When?
18. What do you with the AED after use?
19. How do you dispose of the electrode PADs?

***Closing Questions***

*Thank you for your responses. To finish this interview, I'd like to now ask you questions about implications with cardiac arrests and AED devices.*

20. What is your advice for bystanders to help a person that is suffering a cardiac arrest?
21. Which will be the benefit in having direct communication (audio or video) with the person that is helping the patient while you arrive at the patient location?
22. Which will be the benefit of knowing the patient's data in advance for the paramedic and emergency units?
23. Which will be the benefit of being able to monitor the patient remotely in the ambulance through the AED?
24. What do you value the most during this the process?
25. If you wish 3 things that AED devices could do for you, what would you wish?
26. What would you like to have to help you to perform better your daily activities?
27. Would you want to say or add something else about any of the questions during the interview?

# Interview Consent Form

Aalto University

# INTERVIEW CONSENT FORM

**Research project title:** Health Design & Circular Economy, Circular Design concepts for chronic diseases through Collaborative Design.

**Research investigator:** Manuel Rosales

**Research participant(s) name:** _____

The interview will take 60 min. During the interview, you have the right to stop the interview or withdraw from the research at any time.

Thank you for agreeing to be interviewed as part of the above research project for a master's thesis in Aalto University. Ethical procedures for academic research undertaken in Aalto University's Design Department do not require written permission where interviewees explicitly agree to being interviewed and how the information contained in their interview will be used. Verbal consent is adequate when the interviews do not involve sensitive personal data. However, this consent form has been provided to ensure that you understand the purpose of your involvement and that you agree to the conditions of your participation. All data will be used only for academic purposes and will remain confidential. Please therefore read and then sign this form to certify that you approve the following:

- The interview will be recorded and a text summary (with partial transcriptions) will be produced.
- You will be sent the summary and given the opportunity to correct any factual errors.
- The transcript of the interview will be analysed by Manuel Rosales as research investigator.
- Access to the interview transcript will be limited to Manuel Rosales and his academic supervisor and advisor, as well as academic colleagues and researchers with whom he might collaborate as part of the research process.
- Any summarized interview content, or direct quotations from the interview, that are made available through academic publication of the thesis or other academic outcomes will be anonymized so that you cannot be identified, and care will be taken to ensure that other information in the interview that could identify yourself is not revealed. If you as an interviewee wish to be identified, as e.g. a top expert in a particular field or relevant topic, the content in context will make explicit that this is with your permission.
- The actual recording will be kept on a separate external secure hard drive.
- Any variation of the conditions above will only occur with your further explicit approval.

Alternatively, a quotation agreement could be incorporated into the interview agreement.

**Quotation Agreement**

I also understand that my words may be quoted directly. With regards to being quoted, please initial text to any of the statements that you agree with:

- ☐ I wish to review the notes, transcripts, or other data collected during the research pertaining to my participation.
- ☐ I agree to be quoted directly.
- ☐ I agree to be quoted directly if my name is not published and a made-up name (pseudonym) is used.
- ☐ I agree that the researcher may publish documents that contain quotations by me.

All or part of the content of your interview may be used:

- In academic papers or new articles.
- Master thesis presentations.
- In an archive of the project as noted above.

By signing this form, I agree that:

1. I am voluntarily taking part in this project. I understand that I do not have to take part, and I can stop the interview at any time;
2. The transcribed/summarized interview or extracts from it may be used as described above;
3. I have read the Consent Form;
4. I do not expect to receive any benefit or payment for my participation;
5. I can request a copy of the transcript/summary of my interview and may make edits I feel necessary to ensure the effectiveness of any agreement made about confidentiality;
6. I have been able to ask any questions I might have, and I understand that I am free to contact the researcher with any questions I may have in the future.

**Paticipant(s) Name & Signature:**_____

**Date & Place:**_____

**Contact Information:**
If you have further questions or concerns about this study, please contact:
Manuel Rosales
manuel.ramirez@aalto.fi
+358 45 249 7779

Aalto University

# PARTICIPANT INFORMATION SHEET

**Study title**

Health Design & Circular Economy, Circular Design concepts for chronic diseases through Collaborative Design.

**Invitation Paragraph**

You are invited to participate in this interview because your experience and area of focus has potential to make a contribution to the further development of this research project.

**What is the purpose of the study?**

The purpose of this study is to find potential future concepts for product, services and/or service-product systems that can be designed in circular economy models in Finland, considering chronic diseases as a study case. The main case is cardiovascular diseases, as an opportunity to improve well-being, decrease waste and resources consumption for Automated External Defibrillators.

**Why have been invited to participate?**

You have been invited to participate in this study because you are familiar with chronical diseases diagnosis and treatment. Besides, your relation with patients and experiences will give insights about the implications from different stakeholders' perspectives.

**Do I have to take part?**

You do not have to get involved and you can withdraw from the study at any time.

**What do I have to do?**

You simply have to answer open-ended questions. There are no 'right' or 'wrong' answers, your personal opinion and knowledge are all that matter.

**What are the possible benefits of taking part?**

You will possibly benefit from the thesis publication, which contains research findings which has not been published before.

**What if something goes wrong?**

If you feel uncomfortable about given questions and you do not want to share your knowledge and opinions, you can withdraw from the study at any time.

**Who is organising and funding the research?**

The organization and funding of the project come from the student (Manuel Rosales) with the support of Aalto University.

**What if I have concerns about this research?**

If you are worried about this research, or if you are concerned about how it is being conducted, you can contact the thesis supervisor **Tuuli Mättelmäki** (tuuli.mattelmaki@aalto.fi) and/or thesis advisor **Cindy Kohtala** (cindy.kohtala@aalto.fi).


Aalto University


A?
Aalto University